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UNACCOUNTED-FOR WATER[1]

BY W. C. MABEE[2]

Courts and commissions recognize the existence of unaccounted-for water and take it into their calculations in fixing rates. Only recently the Wisconsin Railroad Commission in the matter of water rates in the City of Two Rivers, P. U. R., 1926 B, page 769 says:

> It requires considerable expense in the operation of a water utility to keep the mains filled with water under pressure, even if no consumer takes water from the mains. On an average from 30 to 60 per cent (in some cases more) of the water leaving the pumping station is unaccounted for. In other words, there would be at least 30 per cent as much water pumped, if there was no water being drawn by customers, due to unavoidable leaks in mains and service pipes, defective joints or pipes, wastage during breaks, etc.

A rating schedule for water charges must take unaccounted-for water into consideration.

Unaccounted-for water is defined by the Manual of Water Works Practice as "that portion of the water flowing into a distribution system which is not delivered to the consumer." Water waste is defined as "water which is not drawn to serve effectively a useful and legitimate purpose."

There is often confusion as to the meaning of the term "unaccounted-for water," as you will readily discover by studying the

[1] Presented before the Indiana Section meeting, March 16, 1928.
[2] Chief Engineer, Indianapolis Water Company, Indianapolis, Ind.

answers received to the questionnaire sent out by the Indianapolis Water Company.

There is a tendency to group water allotted to public uses, such as fire fighting, flushing streets, sewers, unmetered services, under-registration of meters and underground leakage into a lump and call that unaccounted-for water. Much of this so-called unaccounted-for water is delivered to the consumer and is, therefore, in the language of the definition above quoted accounted for, having served effectively a useful and legitimate purpose.

Water waste is another matter and it may or may not have been measured to the consumer.

If Indianapolis, for instance, were to report its unaccounted-for water as embracing water not metered, but used for public purposes, plus leakage and unauthorized use the report would read 18 per cent of its total pumpage; whereas, if a reasonable allotment of legitimate use to public and other known uses is made, confirming the answer to the definition above given, that is, water not delivered to the consumer, the percentage is 10.7 per cent approximately.

It seems, therefore, that water that can reasonably be accounted for as having been used by the consumer, whether it be the fire department, public street sprinkling, flushing of sewers, water for swimming pools, public parks and municipal buildings or other legitimate purposes, is not unaccounted-for water, although frequently classified as such.

No water works system can reasonably be expected to account for all of the water that enters its distribution mains. There are unavoidable losses due to underground leaks that it would not pay to uncover and repair, under-registration of meters that in some instances would cost more to keep operating at an efficiency of 100 per cent than the value of the water saved. There is an economical efficiency beyond which there would be no profit.

On the other hand, there are large losses in underground leaks, under-registration of meters and unauthorized uses that could very profitably be recovered. Some of these losses which have recently come to my attention I will touch upon later.

An occasional check up should be made for unaccounted for water to keep it within bounds. Unaccounted-for water that exceeds an economic limit is an economic waste; the money value of which will depend upon local considerations, but which will in most instances represent a substantial loss of revenue.

Water that has been purified and pumped represents invested capital in plant, operation, materials, supplies and maintenance. This represents its value and it should be conserved as other commodities are conserved. If, by means of water waste surveys, water prevention, more accurate meter measurements, or other means of decreasing consumption, without restricting legitimate use, a saving can be effected, the conservation of the water supply means deferring the time when additional supply will have to be provided involving a corresponding outlay for boilers, pumps and buildings.

The term "economic limit" implied in the language of E. K. Wilson, Chief Engineer of the Pitometer Company, referring to unaccounted-for water and under-registration of meters, was "that point beyond which more frequent testing brings in returns less than the cost of the work; probably 85 per cent would be a fair figure."

Mr. E. D. Case, Vice President and General Manager of the same company, commenting on this same subject in a recent letter to the writer says: "It is my opinion that every metered city should account for at least 85 per cent of the total consumption, and it is possible by present up-to-date methods to increase this figure to the economical limit."

There is, of course, no hard and fast rule that will apply to all communities alike, and the economic limit in one place would be a different figure in another, depending on local conditions.

ACCOUNTING FOR WATER CONSUMPTION

For years engineers have been advocating a separation of consumption into at least two divisions; one industrial and the other domestic. More divisions are preferable, but these two are indispensable if we are to compare consumption figures. Having acquired the habit of reporting consumption per capita as one figure, however, without reference to the industrial consumption, we go on reporting consumption in this unscientific manner.

We had occasion recently to study the distribution of water in Indianapolis where we are about 50 per cent metered, with reference to ascertaining the amount of unaccounted for water that we were pumping into the system and which at first glance seemed to be a large part of our pumpage. As a preliminary step in making this study we decided to compare our consumption of water with other cities and to that end sent out a questionnaire to several hundred cities, large and small, and widely separated.

These answers have been tabulated and show the data in a condensed form, arranged alphabetically by groups according to population, which is made part of this paper.

The next step was to analyze our pumpage by subdividing it into five groups as follows: (1) industrial, (2) commercial, (3) domestic, (4) public and (5) unaccounted for; tabulating the annual and daily consumption in million gallons and reducing these to gallons per capita per day and to per cent of total pumpage.

The service was itemized as follows:

1. Industrial use. Industrial service included railroads, factories, utilities, manufacturing plants, dairies, ice plants, laundries, etc.

2. Commercial use. Stores, offices, clubs, hotels, office buildings, hospitals, schools, colleges, theatres, churches, barber shops, garages, etc.

3. Domestic use. Apartments and residences.

4. Public use. Municipal buildings, parks, play grounds, swimming pools, fire protection, fountains, parkway sprinklers, building construction, flushing streets, sewers, water mains and ditches.

5. Unaccounted-for water. Unavoidable leakage in mains and services, unauthorized use of water, extraordinary meter slip and water otherwise unaccounted for.

A minimum allowance for under-registration of meters was made or each division where service was metered.

Considering the questionnaire so far as Indianapolis is concerned our studies disclose the following:

Daily per capita consumption	89.3 gallons
Average daily pumpage	34.83 m.g.d.
Per cent of pumpage registered on customers meters	56
Per cent of all services metered	45.8
Per cent of domestic services metered	41
Per cent of industrial and commercial services metered	96½
Per cent of pumpage unaccounted for:	
If underground leakage and unauthorized water only are considered	10.7
If unmetered public uses, under-registration of meters, underground leakage and unauthorized uses are combined	18
Per cent under-registration of meters assumed as about	5
Frequency of meter testing; at least every six years for small meters, yearly for large meters.	
Have studies of unaccounted for water been made?	Yes

These studies disclosed the percentages given above which from an inspection of the tabulation does not appear to be an unusual quantity of unaccounted for water.

No steps have been taken to decrease the amount of unaccounted for water as yet.

COMPARING CONSUMPTION

Statistics are apt to be misleading unless all of the facts and conditions are known. To arrive at a comparable tabulation the industrial and commercial uses must be excluded from the total, because of the wide variation in industrial use of water in the different cities. The remaining consumption represents public use, domestic use and unaccounted for leakage or other loss.

In the tabulation herewith presented we have been unable to check up average daily pumpage and per capita consumption with population figures in many instances, and have observed a lack of standard practice in the matter of reporting under-registration of meters and in unaccounted-for water.

In general, I believe that most water works superintendents consider unaccounted-for water the difference between the quantity of water metered to consumers and the quantity entering the distribution system.

Unaccounted-for water may be classified in the following divisions:

a. Pump slip
b. Underground leakage
c. Unauthorized use
d. Under-registration of meters

PUMP SLIP

It has frequently been found in the absence of a master meter the plunger displacement of reciprocating pumps has been taken as the measure of water entering the distribution system and that the quantity has been grossly exaggerated. Instances have been known where the discharge valve from a pump has been completely closed and the pump has gone on churning.

Allowances for pump slip are sometimes taken as low as 2 per cent, usually as 4 or 5 per cent and it is not unusual to find upon careful test that pump slip may far exceed 5 per cent and may be as much as 30 per cent of the theoretical displacement of the pump plungers.

So that in considering data presented, allowance must be made for the source of the information and the judgment of the person supplying it.

UNDERGROUND LEAKAGE

Underground leakage usually represents the largest element of unaccounted-for water. It occurs at pipe joints, service connections, broken pipe or broken services, at blow-off connections or in valves. It is caused by poor workmanship in making joints when pipe was laid or has developed from settlement, or injury occuring after pipe was laid and is not infrequently due to electrolysis, sometimes caused by the corrosiveness of the soil and often caused by stray electric currents leaving the metal structure.

While it is possible to make pipe joints absolutely tight, a certain amount of underground leakage is considered unavoidable. Engineers often specify a tolerance of 200 or 300 gallons per inch diameter per mile of pipe in 24 hours in new systems. The Pitometer Company considers 3000 gallons per mile of pipe per day a reasonable allowance for unavoidable underground leakage, after all reasonable precautions have been taken to stop leaks.

There are many water systems, no doubt, that have been fortunate enough to keep underground leakage below this allowance, but there are many more that are not so fortunate. For instance, the city of Chicago in 1926 tested 66 miles of mains in advance of street paving, and found underground leakage of 10,000 gallons per day per mile; 90 per cent of which was stopped.

The city of Philadelphia, now conducting a pitometer survey for water waste, found underground leakage on a section embracing 626 miles of pipe, amounting to 10,250,000 gallons per day, or in excess of 16,000 gallons per mile of pipe per day, which will, as a result of this survey, be reduced to a minimum.

During the past eleven years Chicago has discovered underground leakage on 668 miles of pipe, which has averaged about 13,000 gallons per day per mile of pipe.

The city of Cincinnati, in 1925 and 1926, found and stopped leakage amounting to 5,000,000 gallons per day, or 10 per cent of their total pumpage. The survey covered about 800 miles of mains which is equivalent to about 6250 gallons per day per mile of pipe.

The city of Detroit located and stopped leakage in mains and services as a result of a pitometer survey made in 1919 and 1922 amounting to 9,500,000 gallons per day over 1151 miles of mains, which is equivalent to 8300 gallons per day per mile, since which time the city of Detroit has organized its own pitometer department and carry on continuously.

Underground leakage such as that described above was imperceptible on the surface. The leaks were of such a character that the water was readily dissipated into the soil or into the nearest sewer without showing on the surface.

One superintendent wrote that he was able to discover leaks by observing after a snow storm the wet places in the snow and would mark the spots for future attention. Others inspected sewers periodically to discover abnormal flows which would indicate leaks or excessive waste.

Underground leaks, beginning in a small way, may, after the lapse of time, assume substantial size and cause considerable damage by undermining pavement. A break in a water main may exist and continue for an indefinite period, discharging into a sewer manhole and may never be discovered unless a search is made for just such a condition.

Too often service pipes are installed in the same trench, as the house sewer. This is an invitation for trouble, as a leak may occur on the service pipe and the water escape into the sewer without detection.

The aquaphone, or listening device, is often employed to locate leaks. It is often difficult to detect underground leaks by this method in a large city, because of the noise of the busy street.

Blow-off connections into streams or sewers may have been left open. Stuffing boxes of valves are frequently found leaking and in many cases are difficult to prevent. The kind of packing used has a large influence on leaks of this character.

Submarine leaks may be discovered by forcing compressed air into the pipe and observing bubbles on the surface.

Longer lengths of pipe are now being advocated to reduce the number of joints and consequently the quantity of leakage; one-third of the joint leakage can be prevented by the use of pipe in 18 foot lengths.

One of the most enlightening answers to the questionnaire came from the city of Akron, Ohio, which is 100 per cent metered, where the water department has evidently been studying "unaccounted-for flow" for the past seven years. The percentage of unaccounted-for flow for this period averaged 23 per cent, but during the last four months of 1927 had been reduced to 12 per cent of the total pumpage. This reduction was brought about by "conducting a continuous street survey covering hydrant, valve, curb cock, sill cock and general surface inspection."

Unaccounted-for flow in Akron "includes illegal use of water, leakage, street flushing, testing, sewer flushing, water main flushing, construction, fire fighting and meter under-registration."

In Akron practically all new mains are laid by water works force account. "Construction specifications have been changed to require new mains to pass a leakage test of less than 100 gallons per inch mile per 24 hours." "Results obtained average less than 30 gallons per inch mile per 24 hours before actual acceptance."

Here then is a shining example for the water works fraternity to emulate.

Baltimore, with 19 per cent of its domestic accounts and 100 per cent of its industrial and commercial accounts metered, reports 18.4 per cent unaccounted for and allots 8 per cent of this to municipal use and 10.4 per cent to waste (leakage?).

Chicago has a daily per capita consumption of 292.5 gallons and records 31.4 per cent through individual meters, which supply 16.1 per cent of the services. The city engineer reports 10 per cent of the pumpage chargeable to underground leaks, pump slip, etc., and about 7 per cent of this to under-ground leakage.

Cincinnati, which meters all revenue producing consumption, accounts for 75.5 per cent of the total. Water used for fire protection, street cleaning, public buildings, parks, etc., is not metered.

Cleveland, which is 100 per cent metered, accounts for 73.5 per cent through meters.

Kansas City, Missouri, which is 84.6 per cent metered, accounts for 75 per cent of its pumpage through meters, estimates free water at 12 per cent, waste, leakage and under-registration of meters 10.1 per cent and flat rate domestic 2.9 per cent.

New Orleans delivers 47.9 m.g.d. into its distribution system (110 gallons per capita per day), of which 68 per cent is recorded through consumers meters. All of the domestic accounts are metered and all of the industrial and commercial accounts except fire sprinkler connections.

New York City has a daily per capita consumption of 144 gallons, uses 867 m.g.d. and records 26 per cent through individual meters. Three per cent of the domestic accounts are metered and 21 per cent of industrial and commercial. Forty-two per cent of total municipal supply to the city is considered unaccounted for flow and is defined as follows:

Leakage from plumbing fixtures of domestic consumers and free users is estimated to be 25 per cent of total supply to city; meter slippage 6 per cent of total supply; underground leakage from water mains and service pipes 11 per cent of total supply.

The following comment is made respecting efforts to check water waste:

House to house inspections have been made to stop leakage from plumbing fixtures as temporary expedients to conserve supply during time of shortage of water. The saving made during such inspections is lost in about two years time. . . . . Underground waste work has been carried on for a number of years with excellent results, but the size of the force engaged in this work has been too small to cover the city in a systematic manner.

Washington, D. C., reports having located and stopped underground leakage amounting to 40 million gallons daily; the daily per capita consumption is now 157 gallons and the total consumption 68.7 m.g.d., of which 44.2 m.g.d. is recorded through individual meters; 85 per cent of all water services being metered. No record of unaccounted-for water is kept, due to unmetered use by Federal and District Government.

UNAUTHORIZED USE OF WATER

There have been instances where water has been taken from fire sprinkling connections, from services and from mains and not paid for until discovered by the sleuths of the water department. Sometimes this illegal use of water is unintentional, accidental perhaps, but no such user of unauthorized water will admit that water was taken with malice afore-thought.

The illegal use of water is not a recent practice. It was known and practiced in Rome several thousand years ago.

Recently, I happened on to this ad in a comic paper:

Wanted: Burly beauty-proof individual to read meters in Sorority houses. We have not made a nickel in two years. The Water Company.

UNDER-REGISTRATION OF METERS

There is considerable difference of opinion touching the subject of unaccounted-for water as affected by under-registration of meters and it is hardly to be expected that there would be an agreement on this

TABLE 1

Data on frequency of meter tests

NAME	FREQUENCY OF TEST
Baltimore	"Every three years"
Buffalo	"Approximately every two years"
Chicago	"1-inch meter when 400,000 cubic feet have passed through same; other sizes in proportion"
Cincinnati	"Whenever fluctuations of consumption warrant"
Cleveland	"Upon request"
Denver, Colorado	"No regular program at present; are contemplating yearly tests"
Kansas City, Missouri	"When bill indicates meter is off"
Louisville, Kentucky	"Upon complaint"
Minneapolis	"About five years on average"
New Orleans	"Only when they are removed for cause or suspicion"
New York	"When meter readings indicate meter to be out of order"
Des Moines, Iowa	"No set time for testing"
Duluth, Minnesota	"Every four years"
Fall River, Massachusetts	"Only when in need of repairs"
Hartford, Connecticut	"No regular figuring"
Memphis, Tennessee	"Whenever the "unaccounted-for" fluctuation arises"
Nashville, Tennessee	"Only when revenue shows a noticeable decrease"
New Bedford, Massachusetts	"We mean to test every five years"
New Haven, Connecticut	"2-inch and over yearly; small meters every five years"
Reading, Pennsylvania	"1-inch and over annual $\frac{3}{4}$-inch and under every five years"
Salt Lake City	"When meters are repaired"
Somerville, Massachusetts	"We have not reached the point of regularity in this respect"
Utica, New York	"Small meters tested every 100,000 cubic feet; large meters once a year"
Wilmington, Delaware	"No specified time for tests"
Worcester, Massachusetts	"No regular tests but believe two-year periods for the tests of all meters would be an excellent system
Ashville, North Carolina	"No system"
Bangor, Maine	"Once a year"

TABLE 1—*Continued*

NAME	FREQUENCY OF TEST
Burlington, Iowa	"When they come to the shop for repairs or when consumers complain that their bills are too high"
Denville, Illinois	"In accordance with Illinois Commerce Commission as follows: $\frac{5}{8}$-inch meter—150,000 cubic feet delivery or every 10 years; $\frac{3}{4}$-inch meter—300,000 cubic feet delivery or every 5 years; 1-inch and 2-inch and over every four years"
Stamford, Connecticut	"Public Utilities Commission requires a test every 60 months. We test 2-inch meters once a year and larger meters twice a year"
Wilkinsburg, Pennsylvania	"$\frac{5}{8}$-inch meter when brought to shop for repairs and under rule of Public Service Commission when 50,000 cubic feet have been registered, or at least once in ten years. $\frac{3}{4}$-inch meters when 100,000 cubic feet have been registered, or once in eight years. 1-inch meter when 200,000 cubic feet have been registered, or once in six years. All meters above 1-inch once in four years"

TABLE 2

Composite water consumption of cities responding to questionnaire

NUMBER OF CITIES	TOTAL POPULATION OF CITIES	PER CAPITA CONSUMPTION PER DAY	PER CENT OF PUMPAGE OR SUPPLY ENTERING DISTRIBUTION MAINS REGISTERED BY INDIVIDUAL METERS	WATER ALLOTTED TO UNMETERED PUBLIC USE, UNDERGROUND LEAKAGE, UNDER-REGISTRATION OF METERS UNAUTHORIZED USE OR OTHERWISE UNACCOUNTED FOR
		gallons		*per cent*
160	25,394,427	98.67		
123			71.66	
121				24.72
Average....	158,715			

subject, since the conditions surrounding the standard practice of different communities respecting meters vary so widely.

Independence, Missouri, has this to say:

It is our opinion, based on some rather careful tests, that the under-registration of meters in service is generally placed at too low an estimate. We have had some rather startling disclosures on domestic, as well as the larger industrial services. We cannot help but believe from the examination of different reports where the percentage of unaccounted for pumpage is set up, that most officials have, like ourselves, been prone to lower the odious "unaccounted for" statement at the expense of estimated flat rate or other unmetered legitimate use.

Mr. George G. Earl, General Superintendent of the Sewerage and Water Board of New Orleans, places his "guess" at 30 per cent. In answer to the question "How frequently do you test these meters for accuracy," Mr. Earl comments thus:

Only when they are removed for cause or suspicion. I cannot see where the *accuracy* of the meter enters, since all ⅝-inch meters on small consumers will not record anything at say 100 gallons per day of small constant waste drafts, and often will not record on double this rate, and such rates of constant waste are of frequent occurrence.

New York City estimates the under-registration of water meters to be 25 per cent of the recorded consumption and Wm. W. Brush, Chief Engineer of Bureau of Water, makes this comment:

Meter slippage is due most to meters too large for the service. Meters are owned and maintained by the consumer which makes it difficult to apply simple remedial measures.

On the other hand, Rochester, New York reports that the average percentage of under-registration of meters is "not over 2 per cent;" Chicago says "3 per cent on disc meters;" Buffalo 2 per cent; Baltimore 1.75 per cent and so on.

Mr. E. D. Case, Vice President and General Manager of the Pitometer Company, who has had considerable contact with meter testing, in discussing allowable slip on domestic service meters expressed the opinion "that in a well operated plant the slip should not exceed more than 5 per cent and may be kept as low as 3 per cent if proper methods are used."

Many cities of considerable importance have apparently given little thought to this subject and are not prepared to venture a guess, and

in some cases where they have attempted to answer this question the answer has been based on shop tests at normal flows.

That it is possible to have large unrecorded flows and under-recorded flows due to "small constant waste drafts," as Mr. Earl expresses it, there is no doubt.

Only recently, the Indianapolis Water Company conducted tests on eight $\frac{5}{8}$-inch meters, taken out of the system, having been in service from one and a half to four years, and tested these meters at minimum flow and at full flow. The average results from this test indicated that with a minimum flow of 252 gallons per day the under-registration was 21.3 per cent, while the same meters at full flow indicated an under-registration of 0.75 per cent. By minimum flow is meant that flow at which the meter began to function, or the least flow necessary to start the meter.

The subject of under-registration of meters is one which offers a large and fertile field for original research, as there is much need for more and better information.

METER TESTING

There is also need for standard practice rules and regulations governing meter testing inasmuch as the accuracy of meters effects "Unaccounted-for water." Some cities have adopted definite testing schedules. Many cities remove and test meters when they stop functioning or when there is a suspicion that the meter is not properly recording flow or when "marked variations occur," "ten years on the average," "when they stop." The city of Akron, Ohio, states "industrial and commercial meters are read weekly and consumption data curves prepared. When discrepancies appear a field test is made."

Table 1 shows the data on the question of meter testing. In general the period set for testing meters where a rule is followed appears to be five years.

DISCUSSION

Mr. Moore: Mr. Mabee has given a great deal of thought to the preparation of this paper. I hope there will be some discussion. I should like to ask Mr. Mabee how he estimates consumption for unmetered water.

Mr. Mabee: Unmetered domestic use in this city is based on services. The general average of the number of persons per service in Indianapolis is five and one-half. Eight thousand water services would mean 40,000 water users, figuring five persons per service, and figuring around 50 gallons per day, I have arrived at the unmetered domestic use.

As to the metered domestic consumption, the average daily per capita consumption is 37 gallons. The weighted average is 37 gallons per capita per day for domestic consumption. If you overestimate the consumption of unmetered domestic water that will make a difference in the unaccounted-for water. The factor of free water is important. Where schools, city use, even the use of flushing sewers by hose, are metered, that shows in the results as about 20 per cent of the unaccounted-for water.

Mr. Durbin: We have 100 per cent meters at Terre Haute and 10 sprinkler supply systems. We find consumption is about 120 gallons per consumer, 24 or 25 gallons per person. Our actual is 120 gallons per tap or per live consumer. We have in Terre Haute a master meter totalling 83.5 per cent actually registered. We do not have any way of determining fire hydrants, sewers, fires, flushing and distributing free water and we have no way of accounting for that. We estimate 5 per cent is accounted for under meter slip, and 10 per cent under-registration and unauthorized. In regard to testing meters I will say that we have placed quite a few meters on the test bench during the past few years. Ten or 15 per cent of the 100 gallons per day will slip through them, that is, they register within 90 per cent of the actual amount. There is a great amount of wastage due to small drip from the faucet, and 5 per cent would be a minimum allowance.

Mr. Brossman: I should like to ask about pump slip. I am not quite clear about pump slip. Is the pump slip included in the 24 per cent? Why should pump slip be included? That water is never getting into your mains. I do not think that is correct, but I can see your side of it.

Mr. Mabee: Most people discount slip before they set up 100 per cent. After they set up they do not take pump slip into consideration, making a reasonable allowance for pump slip in advance. The point is well taken.

THE DESIGN AND CONSTRUCTION OF SMALL FILTRATION PLANTS[1]

By H. K. Bell[2]

The capacity of filtration works intended to be covered in this paper are those ranging from 100 to 1400 gallons per minute and serving communities of from 1000 to 10,000 population. The majority of the plants that have been included in the writers personal engineering and construction experience have been built for towns having populations of from 2000 to 3000. The usual capacity for towns of this size has been the one-half-million gallon plant, usually in two units. The smallest city plant so far built by the writer has a capacity of 200 g.p.m. or 288,000 gallons per day for a town having about 1500 population. Preliminary design has been made for one plant for a capacity of 100 g.p.m. for a community of about 1000 people. The largest plant the writer has built has a capacity of one and one-half million gallons per twenty-four hours or 1050 g.p.m. A two-million gallon plant for a city of about 7000 population is in its preliminary stages. The design of larger plants with units larger than one half million gallons daily capacity would be considered to come within the range of works intended for medium sized cities, works whose general layout and problems of design and future operation are more like those intended for the larger cities. The limits defined are considered by the writer to be an engineering field presenting problems peculiarly its own, many of which are not encountered in the experience of those who have been connected with the works of larger cities only. To explain these problems and to show how they have been worked out in the writer's experience is the purpose of this paper.

The principal factors determining or modifying the design of small purification works are:

1. Available funds
2. Probable demand

[1] Presented before the Kentucky-Tennessee Section meeting, January 21, 1928.

[2] Consulting Engineer, Lexington, Ky.

3. Character of supply
4. Reservoir storage
5. Operating force
6. Character of power for pumping
7. New layout or addition to old pumping plant
8. Topographic characteristics of site and grounds available
9. Probabilities of future expansion
10. Climate
11. Fire service

On account of the large number of varying conditions encountered, the writer has never found it possible to use an old design in a new location. Some years ago before the demand for water supply improvements revived after the war the writer, while working in a different line of engineering, undertook to make use of his spare time by making standard designs for filter plants with capacities of $\frac{1}{2}$, $1\frac{1}{2}$ and 2 million gallons daily. The studies in these designs may have proved good exercise, but, needless to say, none of them have ever been used in practice. This idea of standardization grew out of the writer's experience in designing concrete bridges for the State Highway Department where superstructures having similar spans and widths may be repeated in hundreds of cases thereby saving greatly in expense of design. With water purification works, however, the writer has found that no two problems are enough alike in their factors to avoid a new design in each case.

Taking up briefly the items influencing the design, the writer has the following remarks to make regarding each:

Available funds. As funds available for improvements to small water plants of the class covered by this paper are usually very limited and the necessity or advisability of the improvements and their success often doubted by those furnishing the money, the first and foremost question in the study of a new project is how much money is available or how much can the client afford to spend. Rarely is there sufficient money to avoid cutting out or cutting down on some of the less necessary features or is there any to spend for architectural effects. After determining the capacities required, the money available will influence the size of settling basins, determine whether one or duplicate compartments will be built, influence size of clear well, source of filter wash, character of gauges and controlling equipment, materials for drainage, intake layout and equipment, system of heating, chemical feed and handling equipment and storage, character of materials for housing and extent of building.

The problem of building a purification plant to suit the purse of the client is similar to that involved in the purchase of an automobile. There are cars in the utilities class ranging in price from \$500.00 to \$2,000.00 any of which will carry the owner over the road. Similarly filter plants in the half million gallon class can be built from \$15,000.00 to \$30,000.00 depending upon equipment, housing and size and character of appurtenances.

Probable demand. The probable daily demand will largely determine the capacity of the works to be built. A town of 2500 will usually require 100,000 to 125,000 gallons per day with a metered system or about 50 gallons per day per capita and, without meters, will usually consume 250,000 to 375,000 gallons per day or 100 to 150 gallons per day per capita. Figures as low as 30 gallons per capita and as high as 150 gallons have come within the writer's observation. Usually new filter plants are wanted on unmetered supplies, if for old works, and metering usually follows closely after installing filters. In fact the filtering of the water is frequently a necessary condition to the successful use of meters, as in the case of sandy river waters and well waters with a high iron content. A safe basis for estimating demand, where there are not unusual industrial and commercial conditions and water is to be used mainly for domestic purposes, is 50 gallons daily demand per capita where meters are in use or intended and 125 gallons where water is sold on flat rates.

After determining the probable demand, the capacity of the plant to be built will then depend also upon one or several of the other factors. For instance, a metered town of 2500 inhabitants will consume 100,000 to 125,000 gallons of water per day. A filter plant having a capacity of 200 g.p.m. or 12,000 g.p.m. will furnish this in from 6 to $10\frac{1}{2}$ hours, and would in some cases, prove sufficient. Other factors such as fire service, operating force, reservoir capacity and probable future growth will usually determine in favor of a half million gallon, or 350 g.p.m. supply for a town of this size.

Character of supply. The majority of water supplies in Kentucky are from surface streams. Impounding reservoirs for surface supplies probably come next. Ground water supplies from wells probably come close to the reservoir supplies in number, while a few springs also furnish all or part of the supplies for some communities. These large springs usually are from underground streams in cavernous limestone and fed surface water from sinks in time of heavy rains. Hence they have most of the characteristics of surface

streams in all but temperature and the carrying of leaves and other drift.

A supply taken from a stream subject to wide and sudden variation in turbidity and depth will naturally require a filter plant having an entirely different layout and dimensions of some important details from one using an impounded supply. The stream supply will usually require larger settling basin capacity, a more elaborate intake and the topography of the site will also be different, calling for a different arrangement of its principal features and building.

An impounded supply usually has but a small and slowly changing range in turbidity, hence large settling basins are not usually necessary. The intake in this case can usually consist of merely an adjustable suction pipe with some system for controlling from a bridge or shore. The addition of an aerator is usually desirable for impounded supplies in order to assist in the removal of odors caused by algae during the summer months. Impounded supplies can frequently be built without the use of raw water pumps by placing plant below impounding dam, the raw water being delivered by gravity to the filters.

Well water supplies in this state have been given treatment for removal of objectionable elements in but few cases. A number could be softened to advantage, while quite a few more need treatment for iron removal. As softening is comparatively expensive for treating entire city supplies, this is being practiced but little except for industrial purposes. Well waters carrying even small iron and sulphur content should be treated for their removal. The iron is precipitated by aeration followed by settling in basins similar to those used for removing turbidity from surface waters. This should be followed by filtration to remove the finer particles of red precipitate and leave a clear water. The settling basins for iron removal should usually give from 6 to 12 hours retention, but filters may be operated at a higher rate than for ordinary turbid surface waters. Aeration may be accomplished by the air lift from the wells, spray nozzles, spray pipes, or water falls, all of which have proved effective in causing thorough chemical action from the iron and oxygen. The aeration removes the sulphide gas.

Reservoir storage. The capacity of reservoir or standpipe storage will influence the design as regards capacity of filters and clear well, especially when fire service is required. This condition existed in a city of about 3000 in central Kentucky where the elevated tank has a

capacity of only 65,000 gallons. In order to keep a reserve for fire protection it was deemed advisable to have a filtered water storage at ground level of about 200,000 gallons, while customary ground storage for half million gallon plants is 25,000 to 50,000 gallons. The supply in this case was a spring supplemented in dry seasons by wells all of which were limited in yield. This fact also had its influence upon the filtered water storage provided. In other words, if hourly yield from supply source is less than average fire service requirements and pressure reservoir storage is too limited for safety, the balance must be made up in filtered water or other storage and this item will increase the cost of the works.

Operating force. As the success or failure in the operation of small water plants depends largely upon the cost of operation, the number of men required to operate these plants is an all important matter. Usually the small pumping and filtration plants combined must be taken care of by one operator. Frequently this operator is required also to read the meters and take care of repair work and extensions. In such cases care must be exercised in the design in order to produce a compact and convenient layout that will require a minimum of effort on the part of the operator in doing his daily pumping and filtering and keeping the plant clean and in proper repair. If sufficient capital is available, it is often best to put a little more into a plant of larger capacity in order to complete pumping in from 2 to 4 hours time daily and release the operator the remainder of the time for other duties. Where electric power is used, a smaller plant can in many cases be made almost automatic and require the services of the operator for only a short time daily for preparing his chemicals and making adjustments, the plant being furnished with an automatic switch for cutting off the power when the reservoir is filled. In order to provide for one man operation it is usually necessary to construct the pumping and filtration works together preferably under the same roof. As intakes are a very frequent source of annoyance the works should also be placed as near the source of supply as possible.

Character of power for pumping. The power used for pumping will make a considerable difference in the design. A steam pumping plant using coal as fuel should have boilers and pumps partitioned away from the filter room for cleanliness. Diesel engine and electric motor driven pumps may be housed in same room with filters and all be constantly under the observation of the operator. The use of

electric power, where it is available from a reliable source and price is reasonable, is preferable from the standpoint of economy and simplification in design and construction. The housing of the pumps required in an electric centrifugal pumping and filter plant requires only little more space than housing the filters and piping only. The pumps are usually placed in an enlarged pipe gallery greatly simplifying the pipe work and the operation. With the use of electric power the operator has no excuse for neglect of his filter operations as all his operating time is released for their attention. The cleanliness of this power also removes all excuses and other alibis for failure to keep the plant in a sanitary condition. It is the writer's contention that a filter plant, being the source of the city's drinking water, should be the cleanest place in town. Diesel engine power has also proved very satisfactory as has natural gas, where price is less than 40 cents per 1000 cubic feet. One operator for the small plant can take care of filters and engine also without difficulty. Steam power requires the services of a fireman in addition to the filter operator for satisfactory operation.

New layout or addition to old plants. The majority of plants designed by the writer have been built as additions to old pumping works. Where this is done, the problems are much complicated, as new work must be joined with the old; architectural features (if the old plant has any) must be followed or continued in the new building; the old plant must be kept operating during construction and new piping connections made with old ones in use. The designer has not the choice in this case that he has when building an entirely new layout. Hence, plants built under these conditions are entirely different in appearance from any built independently. One idea in such cases is to save all the old building and equipment possible, much of which is off standard and requires a great deal of measurement and care in working it into the new equipment.

Topographic characteristics of site. These vary with every stream bed and bank. One stream will have a bank 15 feet high while another will be 30 feet or even higher with ranges in floods from 10 to 35 feet. In one case the site will present a shelf or river bottom where all parts but intake may be built conveniently above higher water; another will require that settling basins and filter walls be supported from the river bed upward, sometimes with a height of 35 feet. In one such case the plant is a three story affair with intake beneath on solid rock, clear well next with depth of 8 feet and set-

tling basin on top with depth of 16 feet and a 15-inch concrete floor between.

The extent and shape of the grounds available will necessarily determine the dimensions of the works where these grounds are limited.

Probable future expansion. Probability of future growth of the city and increased demand should be taken into account in the study of all prospective improvements. This condition is much less important in the case of the average small town plant than the larger cities for the average county seat town usually grows but little in our state unless there are mining developments in the vicinity. Where there are indications that enlargement is likely within a dozen years the plant should be designed for a minimum of extra work in its duplication. Usually the plant may be designed so that it may be doubled in capacity by duplicating the settling basin and filters and pipe gallery alongside or by end extension. Where electric power is used the pump capacity may usually be doubled without enlarging the pump room. The same wash water tank built for washing two filters may be used for four or six. The same chemical storage and chemical and chlorinating apparatus will answer for the enlarged plant. In many cases the same clear well will also answer. The writer's practice is to place sleeves in walls for future pipe extensions and to locate the present works so space will be available for future expansion in cases where such growth is likely.

In many cases the demand is reduced by the use of meters after the purification works are installed and a plant built to operate 8 hours a day does its work in from 2 to 4 hours. In such cases the community must triple in size before additions will be advisable. In some cases that seemed to warrant it, a third filter in the same housing has been installed in the original construction and left unequipped until needed later. The expression, a third filter, is used since common practice in works of the sizes under consideration calls for the use of two units. Engineers have been rarely called upon to enlarge works of this nature in the small cities in this state.

Climate. Climate influences the design to the extent that certain materials and equipment must be protected or built in such a way that they will be safe from frost action. Customary practice has been to build basins open and unprotected south of the Ohio River, however, the writer's experience has shown that this is unsafe in this climate, although not more than one winter out of five is severe

enough to cause damage. Nearly all open settling basins observed, whether built by the writer or others, show signs of disintegration of concrete about the water lines. Such structures should be roofed over and buried as much as possible beneath the surface. Inside surfaces should be painted with an asphaltic covering and every precaution taken to make all concrete as nearly impervious as possible, as the least dampness penetrating even part way into the walls may at some time cause frost and its bursting and disintegrating effects. Corners should be cut across diagonally so as to thicken concrete at these points and special reinforcement placed across near inside of walls. Frost seems to have a way of attacking basins at the corners where there is double exposure and a tendency toward cracks on the inside from the nature of the stresses in a rectangular basin.

Fire service. Usually fire service is included in the functions of a city water supply. This service will place a limit to the cutting down of capacities of filters and clear well storage which might otherwise frequently be cut in half to save construction costs. The half-million-gallon plant (350 g.p.m.) is as small a capacity as can be made to furnish this service. When filter plants are built smaller than this, dependence for fire service must be entirely upon reservoir storage or such storage in combination with enlarged clear well and pumping capacity.

SPECIAL FEATURES IN THE DESIGN OF SMALL PLANTS

Grouping of parts. Compactness and economy in design and convenience in operation are largely controlling factors in the grouping of the various divisions of a filter plant.

Filters. The writer's practice has been to build in two unit plants having capacities of one-half to one million gallons. Below the one-half-million-gallon size, one unit plants have been built for economy's sake. Above the one-million-gallon size the practice has been to use the one-half-million-gallon unit for whatever number of units are required, using a sand area of 200 square feet for the unit of this rating or 400 square feet to the million gallons per twenty-four hours. Half-million-gallon pumps usually have a range of 300 to 415 g.p.m. between empty and full reservoir and the oversize permits of the larger draft.

V-shaped concrete wash troughs are used. Concrete construction prevails in the building, so this material is easily adapted to this purpose.

Strainer systems are of the writer's special design, mainly of concrete construction also, and, with exception of $\frac{3}{8}$-inch brass nipples and glass traps, are built on the job.

Gauges, controllers and meters. The type of gauges used is determined mainly by available funds. For one-million-gallon plants and larger the customary practice has been to use gauges of the floor stand and dial type usually four in number; two "loss of head," one "clear well" and one "wash water tank." For smaller plants the practice has been to use float tubes with painted board and indicator gauges. In the construction of plants smaller than one million gallons daily, such matters as fancy gauges, intricate rate controllers, dry feed chemical machines, venturi meters, operating tables and, in very small works, valve stands can be made to form a very large part of the cost, the proportion being out of reason when compared with the other construction. It will be seen that these items are almost the same for a half million gallon plant as for one twice as large. Hence the necessity of other and cheaper substitutes. Although any engineer likes to see nickel plated gauges and appliances in a filter plant, the board gauge shows the operator everything the more costly one does and is more easily kept in working order.

For a rate controller the writer has developed a combination of orifice box and float valve control for the filter effluent which gives a visible discharge in a white tile lined box. This same device is so placed in relation to the clear well that it acts as a clear well control also within certain limits. For instance, when pumps are first started with clear well full and reservoir down, they pump faster and the well drops leaving orifice free. This causes the filters to increase their rate to the limit set. As reservoir fills, pumps slow down and the clear well rises, finally flooding orifice and reaching the point where filter output and pumping are balanced. When pumps are shut down clear well fills and floats cut off filters.

For plants of one-half million gallons and smaller, ordinary meters of the impulse turbine type have been used. The half-million-gallon plant can be serviced by a 4-inch meter with a loss of less than 3 pounds pressure and at a cost of about $175.00, which is about half the cost of an integrating and recording flow meter and about one-fifth the cost of a venturi meter. The ordinary meter set in the discharge line will not give the rate of flow on a chart as will the other types, but it gives the operator and the water company a record from which daily consumption can be checked. The performance of the

pumps also can be checked from the same source. For the one-million-and-a-half-gallon plants a 6-inch meter is required. This costs about the same as the flow meter, orifice type, so the latter is the logical device in such plants. These cost about $360.00 installed and are furnished with daily charts recording the pumping rates and giving in figures on a dial the total quantities pumped. In the writer's opinion, no water plant however large or small should be without some such meter as the knowledge so obtained forms the basis for all estimates for improvements, comparisons of costs of operating, checking waste and leakage, power costs and chemical dosage.

Filter wash. For reasons of economy, plants smaller than one million gallons daily have been designed to use the high pressure from the main lines to reservoir for back wash to filters. A wash pump or a wash water tank will cost from $1500.00 to $3000.00 installed, which is quite an item for the small plant. For one million gallons and upwards, the writer's practice has been to build a wash water tank filled from high pressure discharge line and controlled by a float valve. For a plant now under construction, the wash water tank will be filled from the clear well by a special pump of 100 g.p.m. capacity and with 3 h.p. motor. This will save the waste in electric current otherwise required for pumping the wash water against a 260-foot head as against 50 feet. The cost will be about $250.00 for this pump installed and saving in current should pay for it in a little over a year. Where power is supplied within the same plant, the saving will not be so noticeable and with some plants would not be practical.

The writer's practice has been to build the wash water tank in the roof of the building over the filters. This is easily done with concrete construction and water tightness not difficult to obtain as depth of water is usually not more than 3½ feet. The head used is about 23 feet average on the wash troughs, allowing about 10 pounds pressure for washing purposes. The flat shape of this tank gives a nearly uniform washing head. Tanks are built to contain 30,000 gallons, which is sufficient for washing two half-million-gallon units. The cost of such a tank for extra concrete and brick work added to the building is from $1500.00 to $1600.00 or about the price of a wash pump and motor.

Chemical storage. The chemical storage for plants smaller than one million gallons is usually taken care of in an outside frame storage

shed. Plants of this size usually have housing areas too small for much storage of materials. The chemical feed apparatus is usually on the operating floor in these plants and no partitions separate it from the rest of the building. It is advisable, therefore, to carry chemicals in pails or bags as required in order to keep the operating floor in a neat condition.

For plants of one million gallons and upward the practice has been to provide storage for one car load of alum and a reasonable supply of hydrated lime, which can always be purchased locally as wanted. This storage is provided on floor in space between operating floor and wash water tank. Materials are hoisted from trucks to the door at this floor level from outside and stored at convenient location for loading chemical feed hoppers through openings in floor. Chemical feed apparatus is housed in room containing mixing chamber equipment and partitioned from other parts of building for preventing dusting and slopping with these objectionable materials.

Mixing devices. Smaller sized plants have been provided with timber baffled mixing chambers, preferably shallow in design for construction and cleaning convenience. These mix the raw water and chemicals by agitation from reversing direction of flow and are designed to provide 15 to 20 minutes retention.

Larger plants are being designed with an agitator of revolving paddles for stirring the raw water during the mixing period of 20 to 30 minutes. Both systems have given satisfactory results, but the mechanical agitator produces a larger floc that is more quickly precipitated in the settling basin. Agitators may be driven by either water or electric motors with speed reduction gears.

Settling basins. These are usually designed to give about 4 hours retention period with an allowance of from 12 to 20 per cent of dead space. Larger basins have been built for 6 to 7 hours settling time where extremely muddy waters have been encountered. The tendency in design has been towards cutting out or reducing baffles and allowing lower velocities in a straight line. These velocities range from 10 to 17 feet per hour as against velocities as high as 30 feet per hour with baffled basins. The lower velocities give greater efficiency in sedimentation, provided proper distribution is maintained over the cross section of the basin. This is done by means of distributing inlets and outlets and perforated walls. Sufficient drainage outlets with convenient facilities for washing should be provided. When washing of settling basins is made difficult by the

design this matter is naturally neglected in operating. Convenient connections for $1\frac{1}{2}$ to $2\frac{1}{2}$-inch hose with racks for holding and convenient manholes with permanent ladders assist in this work as do also outlet valves with stands over tops of basins.

Drainage. Inside of buildings the drain pipes are usually of cast iron soil pipe or sewer tile encased in concrete. Ample drain pipes and abundance of floor drains assist greatly in keeping the plant in a liveable, presentable and sanitary condition. Main drains from filter wash must be of ample size or washing can not be effective. A one-fourth-million-gallon unit requires a 12 inch drain pipe from building and a one-half-million-gallon unit requires 15 to 18 inches depending upon length and grade. Drippings from condensation on pipes and waste from pump priming cause a nuisance if not properly disposed of. Floor gratings with pipes or troughs beneath can frequently be used for this purpose.

WATER SUPPLY AND INSURANCE ESTIMATES[1]

By Frank H. Jones[2]

In considering insurance estimates we naturally think of fire. Greek mythology tells that fire was brought to earth by a god, and afterward fire was revered as a gift of the gods. History gives us fire worship and sacrifices were made to the god of fire. We also learn that mud was first introduced as a natural enemy of fire to put it out. Later seafaring people discovered that water would quench fire better than mud. Consequently, we have from the earliest history the use of water in fighting fire.

As early as 450 B.C. the Persians thought fire to be a god. In 289 B.C. a machine was used named Siphonaii, to throw water on fire. Hero of Alexandria, in his treatise on pneumatics, written probably 150 years before the Christian era, described a machine which he called the siphon, used in conflagrations. In these early days water was carried by buckets and put in the reservoir of the machine which was to throw it.

The earliest reference I could find to water works was in the Egyptian period, but I was unable to get very much information as to the water works of that period. We learn more about the aqueducts of Rome. The earliest aqueducts were tunnels. The Romans developed the use of the masonry conduits carried across the country on tall, arched piers. It is this type of construction which is generally associated with the name "aqueduct." Rome was supplied with water by eleven aqueducts, constructed between 312 B.C and 226 A.D. The longest of these, the Anio Novus, had a length of 62 miles. England was the next country that I could find to use aqueducts to supply water to municipalities.

The muncipal fire department of ancient Rome was little behind the departments of the present time, and used large water squirts on wheels. The equipment of the present time is much advanced, but the organization of the present day fire fighters is no better than the organization of those days.

[1]Presented before the Illinois Section meeting, March 30, 1928.

[2]Publisher, Illinois Inspection Bureau, Chicago, Ill.

The earliest engine introduced for fighting fire in the United States was at Bethlehem, Pa., in 1763, and, when tested, threw a stream 75 feet high. It cost $400.00 and was brought from England.

I was unable to find reference to insurance until many centuries after the use of water for fighting fire. The earliest definite record of insurance was in 1240, when certain districts levied assessments on members of the community to provide money to take care of losses through calamity which might arise.

The first definition of insurance occurs in the Statutes of Queen Elizabeth, dated 1601. The first time that the subject is referred to in English Law Books the fundamental principle of insurance is expressed. It has been sanctioned by the experience of the centuries since. The statement was that "By means of a policy of insurance it cometh to pass that upon the loss or perishing of any ship that followeth not the undoing of any man, but the loss lighteth rather easily upon many than heavily upon few."

We find references to insurance in the eleventh, twelfth and thirteenth centuries, and also in the seventeenth century. In the early part of the seventh century, Lloyd's policies were issued for marine coverage. The oldest copy found of a policy was one issued in 1613. Insurance apparently started strongly after the London fire in 1666, which fire aggregated three hundred million dollars loss. A man by the name of Nicholas Barber, at that time, started to write insurance on a commercial basis.

The next advance in the insurance business was in 1700, when Richard Tovey, in addition to insuring houses, offered to insure personal property. This runs along until about 1710, when the two organizations were formed into the Sun Insurance Office, which has been in existence ever since.

In 1700 the Union Fire Office introduced a system of classification which has been carried down to the present time. The first companies to start under Royal Charter were the Royal Exchange and the London Assurance in 1720 and they have been in continuous existence ever since that date.

It is usually considered that the insurance business in the United States began in 1752 at Philadelphia. Later research shows, however, that it existed from 1736 to 1754 at Charleston, S. C. in the Mutual Fire Insurance Company.

In 1752 the Contribution was organized in Philadelphia, Benjamin Franklin being one of the board of directors. This company is

still in existence, and was organized as a perpetual company to cover buildings. Owing to the fact that this company would not write risks with trees standing in front of them, owing to the method of fighting fires, without an additional compensation for the hazard, the Green Tree Company was organized to take such business as would be offered. This is the first known instance where a specific hazard was specifically charged for.

In 1794 the first stock company was organized on this continent. It is still in existence and is the Insurance Company of North America.

In 1866 the National Board of Fire Underwriters was organized, and in 1867 we find the first record of a Daily Report in use, advised by Alexander Stoddard. The evolution of the business has been very great from that period on. In early days fire departments were organized by individual insurance companies to protect the property of the company which organized it. If they ran to a fire and found that they were not interested they would let it burn and go back home. Later these departments were combined into municipal departments.

In considering the above history we find that water works and insurance men are concerned in a business which has endured for centuries. It is very hard to consider one without considering the other. Water works are necessary for the protection of life, health and property. Insurance is necessary for life, health and property.

Insurance is not a mysterious business, but, as we find, has been known for centuries. It is a profession unto itself, but the cardinal principles are easily learned by anyone who will devote any time to its study. We have now arrived at a point in the insurance business where it is the basis of credit. While insurance does not replace materials which are burned, it does compensate the owner for loss that is sustained, thus protecting his credit. Insurance estimates have always been considered with a tone of mystery, yet there is no mystery connected with this branch of the insurance business. The insurance estimate is the basis for the cost of insurance, and is arrived at in a scientific manner. When insurance estimates were first made, a few men would get together and agree on the estimate to recommend. Then schedules of various types were developed, and finally, in eighteen states of the middle west the Analytic System for the Measurement of Relative Fire Hazards was adopted, which explains all of the charges that enter into the insurance cost. This is the only schedule I know of that explains to a property owner, in detail, each

item entering into his insurance cost. The basis of this system is the grading of the town in which we are going to work, to properly classify it. To arrive at this classification, we use the Standard Schedule for Grading Cities and Towns in the United States with Reference to their Fire Defense and Physical Conditions, issued by the National Board of Fire Underwriters of New York City. This Schedule is used all over the United States and the result is the uniformity in the grading and classification of towns of the same protection all over the United States.

The National Board Grading Schedule, to which I have just referred, is a point system schedule, and the largest number of points are given to water works. We have to take into consideration in this Schedule the fire department, the laws, the height and congestion of the buildings. But of them all, water works is the principal subject. We also have to deal with the standardization of hose couplings on the fire hydrants. In the past very little attention has been paid to this particular subject by the engineers laying out water works equipment. You are undoubtedly aware that the standard coupling is $7\frac{1}{2}$ threads to the inch, $3\frac{1}{16}$ inches, outside dimension. The ease with which apparatus may be transported from one town to another, owing to the change in road conditions, is making it imperative that there be a standard connection, if the apparatus is going to be of any value in fighting fire.

The protection of the towns is graded from one to ten in the National Board Schedule, 10 being without any protection, 9 with only chemical protection. Towns graded from 1 to 8 are those protected by water works. There are 425 towns in Illinois with water works protection.

The relation of water works to insurance estimates is reflected in this Schedule more than anywhere else in the insurance estimates, as it is owing to the supply, the pump, mains, hydrants and the ability to keep up a required pressure that the town is graded. It is a deplorable fact that in the smaller towns we find an inadequate pumping capacity, a great amount of 4 inch pipe in the distribution system, an improper and inadequate number of large mains to feed the system, and this is all reflected in our work. When we have arrived at this town classification we are then in a position to make the estimates on the individual risks for the insurance costs. We use a basis arrived at by the loss experience of a given territory. Each individual piece of property is unto itself, except from the

exposure of surrounding property. Under the Analytic System for the Measurement of Relative Fire Hazards we commence with a perfect building and make deficiency charges for construction and charge for the hazards and damageability of the occupancy. We make what we call a survey, showing each deficiency, charged in percentage form, which is then carried out into dollars and cents. In Illinois, we have been working with the property owners and have been sending them what we term an improvement letter, so that if they are interested in reducing their insurance estimates they can do so by eliminating the fire hazards.

On manufacturing property and property protected by sprinkler equipment, we go further and give a report, as well as the improvement letter, to the owner of the property. This includes a fire diagram, so that he may have full information as to his property from our view point. The basis, which is arrived at by loss experience, and the exposure are the only things which the owner of the property does not himself control, and in many cases the exposure can be wiped out by protecting the openings of the building. We publish our results in books for each town and furnish them to our subscribers and to their agents who write fire insurance. Any property owner is entitled to have full information relative to the insurance estimates, and all that is necessary for him to do is to request them from the Illinois Inspection Bureau, or give an agent a signed letter of authority, showing that he is entitled to such information.

The sprinklered property is the risk where water enters into the protection to a greater extent than any other of the buildings in the town, and is supposed to be the highest type of protection. As you are all aware, two sources of water for sprinkler protection is considered better than the single source, and is reflected in the estimates. To protect thoroughly a building with sprinklers, it is necessary that we have at the highest head a certain amount of pressure. We find that it is very difficult at many places to have this maintained by the water works association or company. I wonder whether the water works companies in small towns are not rather short sighted. In the last few years a great many manufacturing interests have been picking out the small towns in which to establish their plants. Most of them have wanted to sprinkler their buildings. Upon making a flow test, we find that sufficient pressure is not maintained for thus equipping the property. While it might be expensive at the time for a company to arrange to maintain this pressure, yet by bringing

that manufacturer to their small town they are going to increase the population of the town, the domestic consumption is going to increase, and they are going to grow so as to get all of the money back. Apparently, however, they are only thinking of the immediate time instead of the future, and do not coöperate to bring about these conditions.

The Water Works Association has an untold field in the State of Illinois. I wonder if you are aware that there are 144 towns with a population of 500 to 800 that are without water works. With a population of 800 to 1000, there are 64 towns; over 1000, 79 towns. I have tried to analyze why these towns are without water protection. Is it because the Illinois Inspection Bureau is lacking in endeavor, or is it from the lack of investigation and salesmanship by the Water Works Association? The total number of these towns is 288, and they are like the virgin prairie that need the plow to turn the soil over. They have to be cultivated and nourished to bring them up to the producing point, or to the point where they will install water protection. You have your duty in this matter and I have mine. There is never a proposed water works that we are not requested to give some idea of its effect on the insurance estimates. We maintain a corps of engineers to assist in bringing about the best development of this sort of protection, and we give this service to the towns free of any charge. We do not attempt to lay out the water works, but we encourage its installation, and are perfectly willing to go over the plans of the equipping company or of the engineer, so that the best insurance costs for the least expense may be obtained. Our work is not over when the water works is installed. We classify the town and make recommendations that it may get a better classification. We watch the growth of the town and recommend improvements to meet this growth. Our work is very broad in this way, as it brings us into the fire department, the building code and ordinances of all towns. We are dealing with officials, encouraging the installation of water works and improvements in the systems already installed. The water works man and the insurance estimator are both working for water works. Each has his own point of view. To the man who is trying to install water works it is his means of livelihood and from an investment standpoint. To the man who is making fire insurance estimates it is for the protection of the financial interests of the fire insurance companies which he represents, by lowering the loss ratio. The largest insurable values are in

cities which have water protection, but there are a great number of small towns and scattered property which need water protection. Our mission is so to coöperate with the water works organization that we may succeed in bringing about this protection.

The evolution of the manufacturing world is such that new hazards and new products are being brought into existence continually. It is the mission of your organization, as well as of mine, to cope with the conditions arising from day to day, and so to equip ourselves that we may be of mutual benefit to the people of our country. We should not ignore the impressions we are making in our work on the minds of children. I can well remember that when I was a child in a small town in Indiana, surrounded by hills, an installation of water works was made, and a pole erected on a public corner to give a demonstration to illustrate the pressure that could be developed. This is as fresh in my mind today as it was when I saw the demonstration. It made a thorough convert of me, as a child, to water works. I have been an ardent believer and supporter of that kind of protection and sanitation since that time.

It was my lot to move into a town in the west that had not developed so as to aspire to a water works. Finally, through the efforts of the progressive citizens, water works were introduced. In looking back upon these instances I can see that if, when men were children, the importance from the standpoint of health, sanitation and protection, and the necessity of water had been impressed upon their minds, they might become the most ardent supporters of that movement.

In the number of towns I mentioned which are without water works in Illinois, it is going to take these younger people to bring about a condition which will demand their installation. Consequently, the children should be taught the necessity of water works for life, health and protection. There should not be a town of 500 or more inhabitants in the country which is not properly protected by water works and sanitation.

FIRE PROTECTION[1]

By Frank C. Jordan[2]

Engineering authorities, who have made careful studies of the problem of reducing America's fire losses, have reached a conclusion which must be met fairly and squarely if the campaign for reduced fire losses is to be crowned with success. That finding is "Prepare adequate fire protection before the fire gong sounds."

Extensive studies indicate that 87 per cent of all of our fire loss is preventable. It is therefore of vital importance that we adopt all sane methods of preventing fire. As long as civilization exists, however, we shall make use of fire and suffer from fire. We are, therefore, confronted with the necessity of preparing for fire in the only sane way in which such preparation can be made.

A realization of individual responsibility in the matter of fire protection is important. The Grading Schedule of the National Board of Fire Underwriters assigns certain relative values in the matter of each class of fire protection and fire prevention service and assesses certain deficiency points, depending upon the extent of variance from the standards adopted for adequate fire protection service. The Schedule provides for a total of 5,000 deficiency points and weights the various services as follows:

	Points of deficiency
Water supply	1,700
Fire department	1,500
Fire alarm system	550
Indirect fire fighting factors such as proper legislation, structural conditions and fire prevention measures	1,250

Fire and water departments may be charged with 3,750 penalty points of the possible total of 5,000. In other words, the authorities who prepared this Grading Schedule upon which fire insurance rates are based, placed 75 per cent of the responsibility of decreased fire losses upon fire and water departments and that responsibility

[1] Presented before the Indiana Section meeting, March 15, 1928.

[2] Secretary, Indianapolis Water Company, Indianapolis, Ind.

must be accepted not only by the water department superintendent and the fire chief, but by the city councils, public service commissions, and other governing authorities who regulate the income or make the appropriations for the fire and water departments.

The educational campaigns fostered by the National Fire Protection Association, and other organizations engaged in reducing America's fire losses, have caused some of the authorities to be more liberal in their appropriations for the fire and water departments. The American public is slowly coming to a realization of the fact that the failure to purchase needed equipment for these departments, or the failure to keep all fire fighting facilities in good condition, usually results in disaster far outweighing the saving.

It is a regrettable fact, however, that some of the governing bodies fail to understand that an inadequate public water supply and an inadequately equipped and manned fire department are very poor economies. The challenge to "prepare adequate fire protection before the fire gong sounds" is especially directed to these authorities.

We have all the knowledge needed for fire protection, costly surveys of cities and regulations for effective use of fire retardants and devices for extinguishing fire, but we have been negligent in the matter of educating the American public to the necessity of applying this knowledge and making it pay dividends in the way of reduced fire losses.

It is a significant fact that in the great campaign against fire waste, the water department is charged with the largest individual responsibility, its share, according to the Schedule of the National Board of Fire Underwriters, being 34 per cent of the full measure of public responsibility in the matter of the protection of life and property from fire.

The waterworks fraternity must give careful consideration to adequate fire service. The part which we play in this great campaign is not spectacular and the general public gives little thought to the importance of the water supply and very little, if any, credit when that supply is adequate, but if there is a shortage of water that fact is immediately seized by the public and the water plant superintendent is bitterly criticized for his failure to provide adequate service. The fault may have been, and in all probability was, with some governing authority which limited his income to a point where he was unable to provide that adequate service.

There must be wholehearted coöperation between the fire and

water departments, otherwise efficient fire protection is practically impossible. There can be no argument as to the shortcomings resulting from a lack of proper coöperation. An inadequate public water supply will make ineffective any fire department no matter how well that department may be equipped. In like manner, inefficient methods or inadequate equipment in the fire department mean inefficient fire protection service despite the fact that the water supply may be classed as Number One by the National Board of Fire Underwriters. More and more cities of the country are giving evidence of this spirit of coöperation and those cities are making inroads on their fire losses.

We of the waterworks field must have a better appreciation of the importance of an adequate supply of water for fire protection and to that end it is advisable for us to "see ourselves as others see us." A recent issue of "Safeguarding America Against Fire" was dedicated to the subject of "Water," and a study of that article will give us a higher regard for the positions which we are holding and the service which we are called upon to render. One editorial paragraph in that issue reads as follows:

> As part of its service in sustaining life water keeps man from burning up in his own fires. It constitutes his chief defense against the Flame Fiend. That it will continue to do so is about as certain as anything in this present unpredictable age. Hence there is no problem more vital than the problem of securing an adequate and continuous supply to every home and every fire hydrant. Truly can it be said that the long history of man's struggle to survive—and, not the least, his struggle to survive the flames—may be writ in Water.

The main article reads, in part, as follows:

Fire's Worst Enemy

> Probably the first question man asked himself after he had learned how to make fire was how to put it out again. He is still asking.
>
> Yet he does not lack extinguishers. Science, in this present enlightened age, has attended to that. Man has such liquids as carbon tetrachloride and carbon dioxide, such semi-liquids as fire-foam, such solids as sand and salt. He owns, or should own, a good stout broom which he wields effectively on occasion. And—he still has Nature's oldest and surest fire extinguisher, the venerable daddy of them all. He has, in a word, Water.
>
> Some day, it is said, he may possibly command the power of music to charm into submission the errant blaze. But that, if it comes at all, will come in the happy, faroff future. Meanwhile, musically speaking, he will content himself with playing the hose from the hydrant.

For, though innovations come and innovations go, when all is said and done, none of man's needs, save possibly air, is quite so imperative as his need of water. It was true in the beginning and it is likely to remain true to the end of time—even in the realm of fire fighting. Despite the frequent utility of synthetic agents and other more homely devices, water is still the most trustworthy means of killing fire. Therefore, if the American fire waste is to be curbed an adequate supply must be assured, both for fire and for domestic consumption, and assured not for today only, but for the long succession of tomorrows. As a problem at once social and economic it is vital.

Water Reigns Supreme

Now in the inspection of cities, as conducted by the engineers of The National Board of Fire Underwriters, the chief item, the one for which the highest allowance is made where it meets the rigorous tests imposed upon it, is water supply. Why this is the case hardly needs expatiation. It must be plain that the most powerful pumper that ever shrieked its way through a teeming metropolis is merely an impotent mass of machinery and pretty red paint if there is nothing, or but little, for it to pump after it arrives at the scene of a fire.

Water, in short, constitutes the life blood of every fire department everywhere; and where the supply is low, or where its delivery is uncertain, a condition of anaemia is set up which affects that city's fire defenses. This weakness, if allowed to continue unremedied, opens the way almost inevitably to the plague of conflagration. Hence the priority accorded by experts in fire protection to water supply, and hence, incidentally, the reason why it figures conspicuously in the price paid by Americans for their fire insurance.

These paragraphs, written by authorities who have given years of study to the matter of adequate fire protection, should be read and reread by city officials, commissions, and others who are charged with responsibility in reference to fire service, to the end that they may have full appreciation of the worth of adequate water service.

Public service commissions are coming to a realization of the importance of an adequate water supply and the following paragraph is typical of commission findings on this matter:

In the construction of a water system in a city or town two services must be provided (1) water for domestic and industrial use (2) satisfactory fire protection. A system designed to give service for domestic and industrial use only, would be less elaborate and expensive than one designed to provide the two types of service mentioned. To furnish fire protection in addition to domestic and industrial service, a higher head of water, greater reservoir capacity and larger mains are necessary, resulting in a much more costly installation and distribution system. Engineers estimate that the investment is increased by making provision for fire protection, from 30 per cent in larger systems to 70 per cent in smaller installations.

The all important words in these findings are "must" and "satisfactory," the commission findings being that "two services must be provided" one of which is "satisfactory fire protection." Decreased fire losses are dependent upon those last three words, namely, "satisfactory fire protection."

During recent years, those in charge of the design, construction and operation of waterworks have realized more fully their responsibility for furnishing adequate fire protection and much has been done towards improving the distribution systems and increasing the volume of water for fire protection. It is now readily understood that "small mains, single outlet hydrants, infrequent gate valves, low pressures and single supply units are features to be avoided even in the village water supply system." It is a regrettable fact, however, that socalled economy on the part of city officials, or others in authority, frequently retards the development of the water plant, this being especially true in the matter of ordering additional fire hydrants where the rate of pay for public fire protection is based on the number of fire hydrants.

Public utility commissions have given careful thought to this matter and the following finding is significant as indicating a broader consideration of the subject of fire service than existed a few years ago.

> In establishing hydrant rates, different systems are adopted, some on a fixed flat rate per hydrant for all hydrants, some on a fixed rate for a certain limited number of hydrants and a less rate per hydrant for all additional hydrants; and a more recent method is that of placing a general fire service charge, based upon the number of inch-feet of main connected with the fire system, and a nominal charge of from \$10 to \$15 per hydrant. This latter method naturally affords better fire protection, as it permits of a material increase in the number of hydrants at a nominal charge after payment of the general fire service charge.

Fire departments, in their work of combating fires, must use large quantities of water, and to accomplish this the mains must be of adequate size and the hydrants must be large in number and close at hand so that there may be short hose lines. The adequacy of the fire protection service of a water plant is based on its ability to provide the required fire flow and the availability of that fire flow through properly located fire hydrants. Engineering experience indicates that the required fire flow in the downtown district of a city of 60,000 is 7,000 gallons per minute. This must be increased to

9,000 gallons per minute if the city has a population of 100,000 and to 12,000 gallons per minute if the population is 200,000 or more. The provisions for the hydrant distribution, with certain modifications as to the size of hydrants, connections, etc. are that the average area per hydrant in the downtown section of the city of 60,000 shall be 70,000 square feet. Where the city is 100,000, the average area per hydrant shall be 55,000 square feet, and where the city is of a population of 200,000 or more, the average area per hydrant in the downtown district shall not exceed 40,000 feet.

Recent surveys in Indianapolis indicated certain deficiencies in the fire flow and hydrant spacing in certain sections of the congested value district, and the Indianapolis Water Company forthwith installed additional feeder mains so that the deficiences in fire flow were corrected. Additional hydrants are being installed which are gradually removing the deficiencies in the hydrant spacings. Reference is made to this work that you may know that our Company does not hesitate to spend the necessary time and money to provide adequate fire service.

In the consideration of our fire losses, we are confronted with the fact that 1 per cent of the number of fires is responsible for 66 per cent of the amount of fire loss. It is, therefore, imperative that we make every effort to provide adequate fire protection service for the high value districts of our cities through better construction, installation of sprinkler systems, improvement of fire and water departments, and every other means which can be applied to such areas.

It is important that the water department superintendent know with certainty that an adequate supply of water is available in the downtown or congested district of his city, and the best known means of assuring himself of the adequacy of the supply is through the instrumentality of fire flow tests such as have been referred to in earlier parts of this paper. Such flow tests are of value in many ways. They clearly demonstrate the adequacy or inadequacy of the hydrant spacing; they indicate the condition of the system with respect to closed valves or other obstructions; they demonstrate whether required fire flows are available at given points; they point out the inadequacy of small lines and furnish good object lessons for city councils or other appropriating or governing bodies. Fire protection engineers find that flow tests are the most practical, economical and constructive method of studying the efficiency of a distribution system. The October, 1924, Journal of the American

WATER WORKS ASSOCIATION carries a very interesting and instructive article on the making of flow tests and their value to water works engineers and every water works superintendent should give careful attention to that article.

Another group in our cities who must assume their share of the responsibility in the campaign towards decreased fire losses are the owners and operators of our stores, factories, warehouses and other buildings in the high value district. This group is under obligation to provide inside fire protection beyond that provided under the term public fire protection. If the water pressure is satisfactory and the volume sufficient, private fire protection systems may be installed and the property made fire safe. All too frequently we overlook the importance of this phase of fire protection service. If this type of improvement should go hand in hand with the improvements in the water and fire departments, our city would make large advancement in its efforts towards becoming a fire safe city. The value of a good sprinkler installation, backed by an adequate water supply, has been demonstrated in thousands of cases, and the saving in insurance premiums will frequently return the cost of such installation in a matter of four or five years. In fact, many Indianapolis property owners have effected such large savings as to return the cost of their investment in periods not exceeding four and one-half years.

During the course of the fire prevention program of Indianapolis, our attention has been directed towards the importance of private fire protection systems, and authorities advise us that we now have a larger number of such installations than are found in cities of corresponding size. Further consideration is being given to this matter and in the near future we will hold a meeting, to which will be invited some 75 or 100 prospects for private fire protection installations, and it is our hope that as a result of this meeting many other Indianapolis buildings will be transferred from the "fire hazard list" to the "fire retardant list."

STANDARDIZATION OF FIRE HOSE THREADS[1]

By J. H. Howland[2]

In the spring of 1920 a movement was started which as sure as the sun rises and sets is going over the top and extend to country wide proportions. This movement is to enable neighboring communities to help one another in effectively combating large spreading fires through the standardization of fire hose threads. Of all fire fighting facilities there is none upon which life and property values are more dependent than the threaded fire hose connections. That such vitally important connections should be universally interchangeable or, in other words, in conformity with the adopted National American Standard $2\frac{1}{2}$-inch fire hose thread is the only sane conclusion.

In the protected cities and towns of Kentucky a great variety of widely different hose threads exist, the great majority of which cannot be directly interconnected with one another. Experience has shown that the providing of adapters to bridge over these misfits has proven costly as well as most unsatisfactory.

From the available records we find that of 54 protected cities and towns in the state of Kentucky the existing threads in 9 are already standard, 1 standard in part, 24 are readily convertible to the standard, 11 convertible in part and 10 are such as to necessitate complete replacement. This would indicate that fully three-quarters of all the existing threads can be standardized at little or no expense, other than the cost of labor in operating the special tools perfected for the purpose under the direction of the National Board. With the remaining 25 per cent the cost of replacement is negligible as compared with the additional protection thereby afforded.

Starting in Michigan and New Jersey seven years ago this movement has gained rapid headway, until we now have it organized and under effective headway in 30 of our 48 states. Of your neighboring states those of Ohio, Indiana, Missouri, Arkansas and Tennessee

[1] Presented before the Kentucky-Tennessee Section meeting, January 19, 1928.

[2] Engineer, National Board of Fire Underwriters, New York, N. Y.

have this work wholly or largely completed. Legislative bills have been passed in Oregon, Massachusetts and Texas making it mandatory for all protected cities and towns in their respective jurisdiction to have the National Standard thread; similar bills are under consideration in Maryland, Idaho and Montana. At the end of the calendar year 1927 our progress reports show that upwards of 2700 of our cities and towns have had their fittings converted to this National American Standard. With a total of something like 8000 protected municipalities in the United States, about a thousand of which were originally standard, it is seen that we are about half way towards the desired goal of country-wide standardization. It is probable that this work will shortly be undertaken in the southeastern section of the country.

In recognition of the importance of this movement to the taxpayers of Kentucky and as a part of the public service rendered by his organization, George H. Parker, Manager of the Kentucky Actuarial Bureau, has authorized me to state that he will coöperate to the extent of providing conversion tools for loan to the communities, and experienced mechanic to supervise the field work and a truck to faciltate getting over the ground. It would seem therefore that the various municipalities and utilities interested in public welfare should get solidly behind this standardization movement in Kentucky and render 100 per cent coöperation in getting the necessary authorizations to proceed with the necessary field work at the earliest possible date.

Any city or state is going to be more and more at a disadvantage from a fire protection standpoint as it becomes surrounded with the one National Standard thread and tolerates the continued use of non-standard connections.

Let us coördinate our efforts and get Kentucky on the list of states having uniformly National Standard hose threads on all 2½-inch fire hose connections.

The engineers of the National Board of Fire Underwriters have through its Committee on Fire Prevention and Engineering Standards been in a position to accomplish much in raising the standard of fire protection in our American municipalities. We are indebted to the officials and superintendents of both publicly and privately owned water supply systems for a large measure of our success. To the Kentucky-Tennessee section of the American Water Works Associa-

tion let me express the felicitations and best wishes of the National Board. We shall look forward with confidence to your coöperating with us in the standardization of fire hose threads and trust that our friendly relations may become even closer in the future than in the past.

INTAKE AND WATER TROUBLES AT MICHIGAN CITY, INDIANA[1]

By Charles Brossman[2]

For the past several years Michigan City has had considerable trouble in procuring water from Lake Michigan. Of course, this had not been due to lack of water. Some of these troubles may be of interest to the Section.

The water consumption of Michigan City is exceptionally high, due to the fact that up to a few years ago there were practically no meters and at present the percentage of meters is rather low. Two things against meters have been the sandy soil, which requires excessive water for sprinkling purposes, and the large amount of fine sand, which has made meter up-keep high.

The sand has also given trouble with the pumps and even the pipe line, as will be shown later.

This sand is of a very fine silty character which seems to come in after a disturbance on the lake. This fine, as well as coarser, sand has leaked into the intake and pipe line, impairing their capacity.

About 2 years ago the writer was engaged to look into the matter of the water shortage and recommended an increase in size of the intake pipe line into the lake. This also necessitated the placing of a new suction well, as it was not deemed advisable to connect any new lines into the other wells and it was also desirable to get rid of as much of the sand trouble as possible.

The old intake lines to the lake were originally 24 and 30 inches in size. The 30-inch line ran down to the shore, a distance of about 1000 feet and from there this line was increased to 42 inches, a distance of 3000 feet additional. This terminated in an octagon shaped crib, with the suction line elbow looking upward. In 1922 the water works superintendent recommended an additional 30-inch line to be run in from the shore. This was not done at that time.

The writer recommended last year that the new line be made 48 inches in diameter to provide for future growth of the city.

[1] Presented before the Indiana Section meeting, February 18, 1927.

[2] Consulting Engineer, Indianapolis, Ind.

In July, 1923, divers were sent down to inspect the intake and reported the crib for the 24-inch line as entirely gone. A new crib was then built and anchored to the 24-inch line with chains and rock. The line itself was leaking in many joints, and the lead caulking had worked out letting in the sand. The repairs on this work were completed in August, 1923, and this line is now supposed to be in reasonably tight condition.

As a matter of interest the reports show that the maximum pumpage in June, 1922, averaged about 10,000,000 gallons per day; for a population of 22,000.

In 1925, the average pumped was 7,884,000 gallons for a population of 26,000 with 4356 water services. The gallons per capita used were 353 per day. It was believed that part of this high consumption was due to leakage. This was afterward found to be true after repairing the harbor line.

After a number of conferences with Mr. Couden, City Manager, and Mr. Wade Swasick, City Engineer, it was decided to make this new extension to the intake line 48 inches in diameter. This was to be connected to the present 42-inch line with arrangement left for connecting the 48-inch main to run out into the lake, at a future date. A junction well was designed to be placed as close to the shore line as possible so that the line as now being built, will consist of a 48-inch from the junction well at the shore line to the pumping station. The junction well also connects the 30-inch line running to the pumping station. This leaves a 42-inch line running from the shore into the lake. The profile of the new line as compared with the old line is of interest. This shows there was a hump in the old line which was only one foot below the ordinary level of the lake.

The superintendent of the water plant advised that at certain times the water level at the lake was lower than the top of the pipe, which, of course, cut the effective head and practically made a syphon out of the line. The shore line in 1914 was close to this hump, whereas, the shore line has now receded a considerable distance.

The new junction well was placed as close to the shore line as possible in order to connect the 42-inch line at a lower elevation. The 48-inch line was dropped even lower so that when it is extended out into the lake, it will be submerged still further at the highest point.

This junction well at the shore line is built around the 42-inch cast iron pipe for a length of one joint. The top was left off of the well and

after the new line and intake well were entirely completed, this one section of 42-inch pipe was cut and taken out and the top of the junction well placed.

The new intake line from the shore is built of 48-inch reinforced concrete pipe with a standard type of joint. These are laid the same as ordinary concrete sewer lines. Some difficulty was encountered at first in getting the first few joints tight as the entire pipe line was

FIG. 1. WELL POINTS FOR DEWATERING TRENCH

practically below the level of the lake. Water was kept out of the trench by well points, which were constantly pumped with diaphragm pumps.

Near the pumping station quick-sand was encountered and for this section of the line a concrete saddle was built before placing the pipe. Approximately 400 feet of this kind of sand were encountered, which made the laying of the pipe very slow and difficult.

INTAKE WELL

The new suction intake well is built entirely of reinforced concrete 32 feet in diameter and 30 feet deep. The lower section was first

built to a depth of about 10 feet. After this the interior was excavated, the weight of the wall sinking the shaft into position. The bottom was in blue clay, which was under quick-sand. Considerable trouble was experienced in keeping the water out, after the wall was sunk, but the system finally used was to place batten boards under the wall and drain tiles were laid from the outside to the center, being laid in cinders. The water was pumped out with a steam jet. The excavation was made somewhat lower than called for to allow for some material coming in. The reinforcing steel was then laid as quickly as possible, concrete rushed into place leaving an open hole in the middle so that the water could rise and not put any pressure on

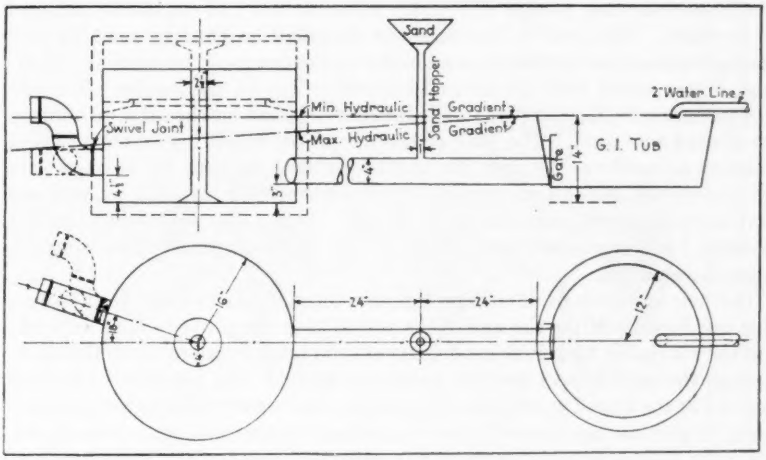


FIG. 2. MODEL FOR DETERMINING LOCATION OF BAFFLES

the concrete. This hole was left in the middle of the well directly under the column, so that when the column was placed, for supporting the roof, it closed the hole entirely.

The well has a concrete balcony around its entire circumference and a reinforced concrete roof and will have a centrifugal pump for pumping out sand.

BAFFLE EXPERIMENTS FOR SAND CATCHING

The inside of the well is arranged with baffles and screens for catching sand which is coarse enough to be settled. In order to get

the most efficient design for baffles, it was determined to make some experiments with a model proportioned exactly as the finished well.

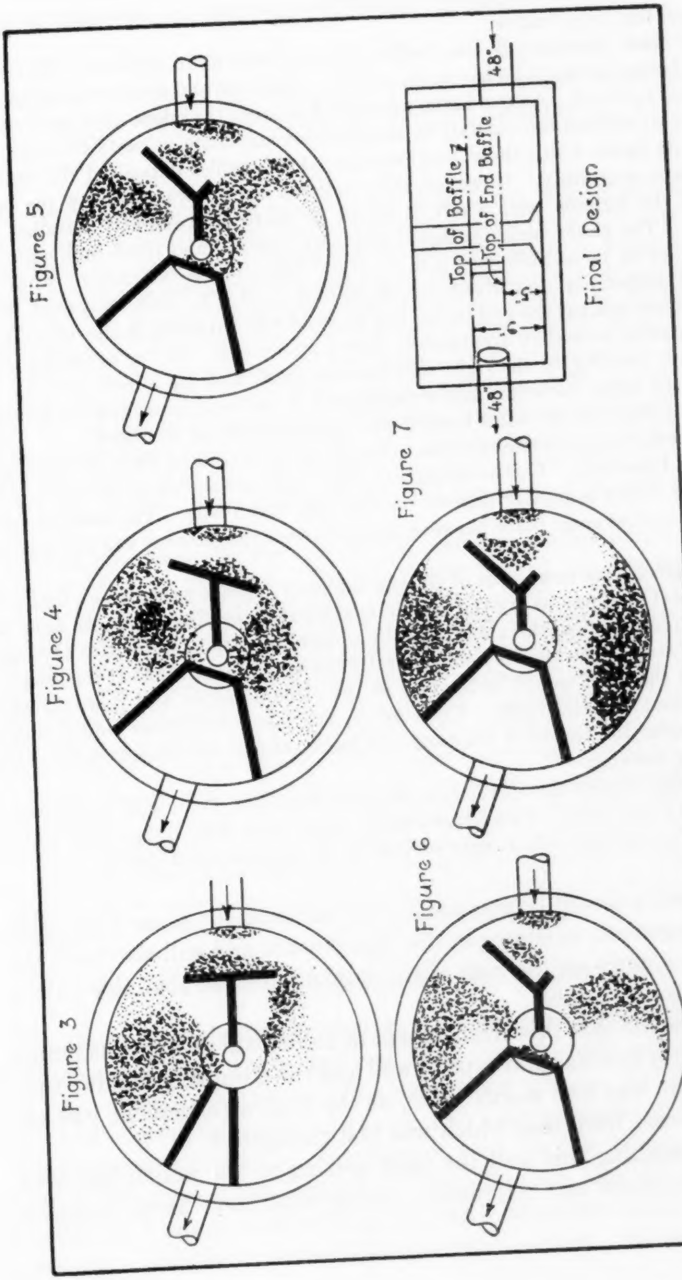
The description and plans showing these experiments are herewith given and were in charge of our resident engineer, Mr. Moore.

In making the experiments hydraulic principles were disregarded in so far as the building of the apparatus proportionate to the large well was concerned. It was necessary to force sand into suspension in larger quantities than natural conditions would show, in order that the deposits could be noted and the experiment concluded in a reasonable time. There were so many elements conflicting with hydraulic principles and not mentioned above that the model was finally designed on the scale of one inch to the foot as shown in figure 2.

The entire model was made of galvanized iron. The tub was filled with a 2-inch line carrying normal city water pressure and was constantly allowed to overflow. The gate in the tub was installed so that by opening and closing it a condition similar to sand in the intake line could be studied. However, it was noted that this had no material effect on the results. The one inch tap marked "Hopper" was made in order to introduce the sand. Common beach sand was used. The plan of the apparatus is self explanatory, being designed as nearly as possible like and to the same scale as the storage well. The goose neck out-fall was made of two ordinary four inch elbows, and one joint marked swivel joint was not soldered. This goose neck controlled the velocity, by being raised and lowered, thus decreasing and increasing the hydraulic gradient.

The first step was to determine the flow through the tank without baffles. This was done by filling the apparatus and setting the goose neck so as to obtain the maximum hydraulic gradient; next red ink was poured into the water through the sand hopper and the result was noted. The apparatus was then emptied of the tinted water and refilled with clear water. The goose neck was raised to give the minimum hydraulic gradient and red ink again introduced. The goose neck was then set at a point to give the mean hydraulic gradient and all the following steps in the experiment were made with the goose neck in this position. Sand was then placed in the hopper and was deposited on the right (facing the out-fall) side of the well.

There was no theoretical starting point known to the writer to determine the location of the baffles. The entire experiment was conducted by the trial and error method. The first baffles were made of wood and placed as shown on figure 3. The results were as indicated. It was evident from this trial that in order to retard the flow through the well as much as possible the water should be forced toward the left hand side. It was also apparent that the water was quiescent from the long baffles to a point 9 inches around the circumference of the tank measured from the center line of the out-fall. While the baffles were in the position described above, the goose neck was suddenly lowered and it was found the opening between the long baffles was not large enough, also sand was carried through the out-fall in sufficient quantities to be caught in a cloth. Most of this sand had been picked up from the bottom



FIGS. 3 TO 7. GRAPHICAL REPRESENTATION OF BAFFLE EXPERIMENTS FOR SAND CATCHING

of the tank by the swirling action of the water through the two small openings between the large baffles.

The next position of the baffles was as shown on figure 4. The long baffles being spread 18 inches apart at the out-fall end and 6 inches apart at the center of the tank. An end baffle was added in order that deposited sand could not be carried into the out-fall by sudden increase in the velocity through the well. As figure 4 will show, this position of the baffles deposited the sand a little more uniformly. However, the condition wanted was to throw the sand toward the outside wall where it could be more conveniently handled by pumps. The goose neck was again suddenly lowered and the 6-inch opening was found to be of sufficient size to allow this sudden increase of velocity without materially disturbing the deposited sand. A little, however, was carried over against the end baffle, but no sand was apparent in the out-fall.

The baffles were then arranged as shown on figure 5. It was apparent that the 2-inch opening on the right side was too small and the 8-inch opening on the left too large; however, this arrangement of baffles approached the desired results by drawing the sand toward the circumference of the tank.

The next step consequently was to lengthen the left hand baffle and shorten the right hand one. This arrangement and result are shown in figure 6. The sand now shows a greater deposit on the right hand side. The natural conclusion was that some place between the last two arrangements was the correct answer.

The baffles were now made of tin and soldered in place as shown on figure 7.

The final step was to try the last arrangement by setting the goose neck at several different elevations and thereby obtaining various velocities through the apparatus. The results were generally the same, except that at the greater velocities the sand would be heavier at the circumference and it would also show against the end baffle. Conversely, the lesser velocities would settle the sand near the center of the tank and more sand would appear just under the intake opening.

In the final design the opening on the right was made 4 feet wide and the one on the left 7 feet wide. Two-hinged gates, 2 feet wide, were hung at the end of each wall to enable an adjustment of flow by being opened and closed.

The final well will be equipped with baffles of the same proportion and arrangement as shown in the experiments and will also have the two hinged gates on the wall of the intake baffle, so that this will be more or less adjustable.

It is believed that this arrangement of baffles will give the maximum efficiency for this size and type of well and the trouble of making such experiments was well worth while, as the final arrangement was entirely different from that which was first thought of.

Since installing this well the sand getting to the mains has been greatly decreased and complaints due to sand have about stopped.

FREEZING OF THE 42-INCH INTAKE LINE

Another matter of interest on this intake is the trouble from cold weather. I am giving herewith information on trouble which occurred in January. The account given by Wade Swasick, city engineer, is as follows:

On Sunday the water was suddenly cut off at 5 p.m. The first idea was that the sand had covered the intake line and stopped it up. At that time, the impression was that the intake did not have the elbow looking upward. It had been supposed that the elbow had been washed out by a storm and that the storms had gradually piled up the sand over the end of the intake pipe. The ice along the shore was very thick, there being about 20 inches of natural ice drift. Two tugs were procured and after a battle of about 8 hours they got outside of the breakwater with a diver on board. After the diver had inspected the crib, he found that the elbow was turned up as originally placed and that there was a 2-by-8-inch timber with 4-inch openings above the top of the elbow. The top of the timber screen was about 30 feet below the surface and ice had formed on the openings on top of the crib. This seemed to be anchor ice.

If I remember correctly the weather had been comparatively mild for two weeks preceding the freeze up. The lake temperature at this time was probably 50 degrees F. The thought that I have is "anchor-ice." On the Wednesday preceding the Sunday that the intake froze the temperature dropped to 10 below and a high wind was blowing with the result that the lake was quite rough. It was impossible for the lake to freeze normally under these conditions, hence fine particles of anchor-ice formed in suspension in the water. When the cold water of the surface started downward as will happen under these conditions, it carried the small particles of ice along. Capillary attraction caused these bits of ice to adhere to the timber screen and the sides of the pipe opening. These tiny bits kept building up until the entire screen was covered and the water frozen solid to the top. In other words, I think the freeze was from the bottom up instead of the more normal order of top down.

This is not an unusual occurrence in these lake towns, as it also happened at Hammond, Whiting, Evanston and Willamette.

TROUBLE WITH THE BREAK ON THE HARBOR LINE

The water from the pumping station is pumped across the harbor to Michigan City. There are two lines, one 24-inch and one 30-inch line. Only a short time after the trouble with ice on the intake line, trouble occurred on the discharge line running under the harbor.

The normal pumpage at this time of year for the Michigan City water works runs about 5 m.g.d. About 30 days ago this average increased to 7 m.g.d. within 24 hours and 3 days later had mounted to 9 m.g.d. This figure exceeded all previous records. It was there-

fore apparent that some tremendous leak existed. Industries were checked for the use of the water. The entire water department checked mains, fire hydrants, etc., but no leak or reason for this increased use of water was apparent. At last a workman took a pole two inches by two inches by eighteen feetand made an effort to locate the 30 inch main under the harbor. The main was too low for this man to reach it, but when he made an effort to lower the stick in the water the force of the leak 10 feet below the surface twisted the pole from his hand. Mr. Wade Swasick, city engineer, was immediately informed and he detailed men with long poles to prod the harbor bottom in order to locate the 30 inch line. At this time the writer was informed of conditions.

No disturbance was apparent on the surface of the harbor nor was the water discolored more than its usual muddy gray. The workman continued to prod until the mud covering the pipe was penetrated. Suddenly the water began to boil up, slime and mud appearing on the surface, and the harbor was fairly black for a radius of 100 feet around the leak.

The diver, William Lehndorf, was called from the Great Lakes Construction Company, Chicago, and was requested to make an inspection and report. At the moment the diver was emerging the fountain of water was swung back and forth for a distance of 20 feet. The size of the leak can be appreciated when it was pointed out that the water was bubbling up one foot high and about 10 feet in diameter. This force was carrying up through 25 feet of water.

The diver reported a broken joint 20 feet from the swivel joint, about 15 feet out from the shore.

Fogelman and Dawson rushed their crane to the harbor and immediately started excavating around the submerged main. They worked all night and accomplished quite a bit, however. The next morning the diver reported that the crane had been unable to reach out far enough to uncover the leak. It was now apparent that the repair job would take considerable time. Fogelman and Dawson's Austin was released and the Subway Engineering Company brought their P. H. crane on the job. Piling was driven and a run way constructed. For 2 days the excavation process continued. The diver then made a third inspection and ordered one 12-foot length of 30-inch pipe and a sleeve. The next job was removing the old section. It was necessary to dynamite in order to remove the bad section. When the broken pipe was brought to the surface true conditions were

discovered. It was evident that this section of pipe had been cracked around the bell, when it was laid 14 years ago. Constant erosive action had worn this crack wider and wider. Even the heads of the inch and a half bolts had been entirely worn away.

After the new lengths had been installed the line was tested with air and another leak was found 30 feet farther out in the harbor. A crack was found running the entire length of one pipe and varying in width from $\frac{1}{8}$ to $\frac{1}{4}$ inch.

The present plan is to replace this broken pipe in the same manner that the other repair was made. Plans are now being made to construct a tunnel under the harbor. I have communicated with the City Engineer pointing out that in our sanitary improvement it will probably be necessary to construct an inverted siphon and that it might be economical and possible to make our harbor crossing in the vicinity of the present 30-inch main and that this concrete tunnel could be constructed to take care of both lines.

From the above it will be noted that, even though there is unlimited water at hand, there is always some difficulty in procuring it. At the present time, we are making a complete investigation of the sanitary and water conditions for Michigan City and recommendations are being made to provide for these difficulties. The city contemplates taking care of sanitary arrangements, sewage disposal and such improvements to the water works as will provide them with a safe, wholesome and clear water.

AERATION OF WATER[1]

By W. S. Mahlie[2]

The word "aeration" immediately suggests to us that oft repeated statement "running water purifies itself," which is so firmly fixed in the mind of the layman. Associated with this phrase is also the term "pure air," and the combination of running water and pure air has quite a psychological effect upon an individual viewing for the first time a large installation of spray nozzles.

If it were not for the fact that the water spraying through these nozzles is sometimes muddy or turbid, a great many people would feel satisfied with no further treatment. This statement, of course, applies only to the average visitor at the treatment works and not to those who are somewhat curious and who may ask "Just why do you do it?" In such cases one is sometimes at a loss to give a straightforward simple answer.

Donaldson has very ably presented this subject in a concise way in the Manual of Water Works Practice, and therein he has also pointed out that a clear, definite understanding of the principles and limitations is still lacking in the minds of many engaged in the practice of water treatment.

Aeration principles appear to have been recognized in design of the Roman Aqueducts, the sides of which were left rough (6).

In the Magdeburg, Germany plant (4) beneficial results of aeration undoubtedly were secured by the cascading from a higher to a lower filter bed.

In France, in the so-called non-submerged filters (5), the water was sprayed into the air continuously over a bed of sand similar to a sewage filter.

As early as 1812, Dickinson and Maudsley (1), proposed to oxidize organic matter by simply forcing a stream of air through the foul or tainted water by means of bellows or pumps.

In 1868 aerators were employed in Germany.

[1] Presented before the Water Purification Division, Chicago Convention, June 9, 1927.

[2] Chemist in Charge, Water and Sewage Purification, Fort Worth, Texas.

Experiments were made by Leeds in 1883, who demonstrated that there was no improvement in the water after passing over Niagara Falls, and that no direct oxidation took place. This was verified by Frankland who said "That to get rid of organic matter by exposure to the air for a short time is absurd."

Nichols, in 1888, points out that,

Although a water colored by vegetable matter loses color when exposed to sunlight in closed vessels, it is probable that the changes which take place in storage basins are due partly to the action of the air. There is no doubt that the passage of water over natural falls or artificial dams tends to its improvement. In the larger reservoirs and ponds the winds play an important part in agitating and aerating the water, but it is very doubtful if any scheme for artificially aerating the water would accomplish enough to pay for the outlay involved.

Dr. Drown, in 1891, in the Report of the Massachusetts State Board of Health, stated clearly the various principles involved.

Fuertes (3) in 1901, says,

The aeration of water by passing it over cascades or falls is popularly supposed to do much toward its purification. The greatest fields of usefulness for this treatment, however, are for the oxidation of iron in solution, the removal of disagreeable gases, the prevention of stagnation, and the retardation of growth of certain forms of vegetal life in the water which by their development impart disagreeable odors and tastes. Generally speaking, aeration is ineffective except for the purposes stated, sometimes it may even have the opposite effect to purification.

Hazen and Fuller's report in 1907 on the New York water supply mentions experiences with aeration at various places. It is of interest to note that they stress the point "that exposure should be in fine drops and not in channels," and that the experiences mentioned were from plants employing slow sand filtration or storage reservoirs alone.

Whipple's (21) experiments of 1907, published in 1913, gave quantitative expression to the results obtained in aerating waters containing carbon dioxide and hydrogen sulphide gases and odors due to oil of peppermint. He pointed out that when water is exposed in drops the carbon dioxide is reduced to 50 per cent less in winter than in summer.

It appears that aeration has been developed in several successive steps, the first attempts being an effort to increase the dissolved oxygen content and possibly the oxidation of organic matter, then

the next step being the removal of objectionable gases such as carbon dioxide and hydrogen sulphide, with resulting precipitation of iron and manganese and finally the sweeping out effect and interchange of oxygen for odor removal.

Since in any chemical or physical reaction the reaction rate is proportional to the reacting surfaces exposed, it follows that the greatest aeration efficiency would be attained when approaching atomization. Tending to offset this would be the splashing effects, evaporation and economic operation. To show this surface effect we might make use of an illustration. If we were to assume a gallon of water in a spherical condition, we would have a sphere about $7\frac{5}{8}$ inches diameter and having a surface area of about 182 square inches. If this gallon of water were to be exposed in a flat sheet of $\frac{1}{8}$ inch thickness such as might be produced by flowing over a weir, we would have a surface area of about 3700 square inches figuring both sides and, if the water were broken up into drops of $\frac{1}{8}$ inch diameter we would have about 10,700 square inches of surface exposed.

Donaldson's (14) experiments at Memphis verify this. In a study of aeration devices for carbon dioxide and iron removal, he tried triple tray coke scrubbers, metal pans with perforated bottoms, vertical riser pipes, riser pipes with splash tables, nozzles with inspirator effect, Spraco nozzles and riffle boards. He concluded that the spray nozzle was the most effective for removing carbon dioxide.

One of the disadvantages of nozzle aeration is the additional pumping head involved. This has led to the development of the Sacramento nozzle or floating type by Gillespie and Hyde (23).

The methods used to bring about aeration are mostly all based upon forcing the water through the air, although there are instances where air is pumped into the water. Such a method was recommended for Waltham Abbey and Rammey Marsh in England (22).

AERATION AND IRON REMOVAL

Simple aeration alone is not always as efficient as it might be in iron removal, but, in order to secure the best results, a roughing filter of some sort is necessary. If iron is rather loosely held in solution, a small amount of aeration is sometimes an advantage over the spray system. If, however, considerable carbon dioxide is present the spray nozzle is best.

The principles of iron removal by aeration are well set forth in the statement of Darapsky (11) translated by Kimberly (12). "The removal of iron from water requires the very intimate admixture of an excess of air (oxygen) following which to secure coagulation the water must be subjected to the catalytic action of previously precipitated iron sludge."

This principle is made use of in the various designs of iron removal plants, and in the so-called Anderson process.

In support of this theory is the experience by Pearse, Greeley and Hansen (13), at the Benton Harbor, Mich., experimental plant where aeration and four and two-thirds hours sedimentation removed no iron, but sand filtration afterward removed all of it.

REPRESENTATIVE PLANTS FOR IRON REMOVAL

Among the earlier plants we find: Lowell, Mass. (7), Asbury Park, New Jersey (8), Reading, Mass. (9), Far Rockaway, New York (8) and Middleboro, Mass.

At Virginia Beach the water supply obtained from wells carried enough iron and odors so that it was unfit for drinking, kitchen or laundry uses. The raw water contained from 100 to 125 p.p.m. carbon dioxide and 2.2 p.p.m. iron. Spraco nozzles surrounded by a louvre fence were installed, and by their use the carbon dioxide was reduced 84 per cent.

At Leroy, Ohio (16) Kimberly designed an aerator followed by roughing filters which removed all the iron present in the water.

Professor A. N. Talbot (17) at Urbana-Champaign introduced raw water into the filters by means of a vertical riser pipe covered with an orifice plate. The raw water contained 2 p.p.m. iron and no oxygen. He obtained a good effluent practically saturated with oxygen.

The water supply at Berlin is aerated to remove iron. Nozzles are employed in which two jets of water impinge on each other, somewhat similar to the old acetylene lamp burners.

Copenhagen is another city aerating water for iron removal.

Donaldson has published results secured at a number of plants. It is superfluous to repeat them here.

AERATION FOR HYDROGEN SULPHIDE REMOVAL

In the utilization of aeration for hydrogen sulphide removal, a rather short exposure is all that is necessary. Pumping wells with

air lift is sometimes sufficient. At Columbus, Ohio, the Buckeye Steel Casting Company pumped water from deep wells with an air lift. A noticeable odor was always prevalent in the vicinity of the wells, but chemical tests at the laboratory failed to show any hydrogen sulphide after it had been discharged into the receiver.

Enslow has found that chlorine reacted quickly with hydrogen sulphide with a resulting precipitation of sulphur. Chlorination before aeration, therefore, would be a better method for eliminating hydrogen sulphide gases than aeration alone when hydrogen sulphide is present in excessive amounts.

De Laporte (27) has mentioned the decreased chlorine dosage of the water at Essex, Ontario, due to the removal of hydrogen sulphide by aeration.

Savings have been effected in one plant using alum and soda ash as a coagulant by reducing the carbon dioxide present in the raw water by means of aeration.

AERATION FOR TASTE AND ODOR REMOVAL

There exists some misunderstanding as to the principles of aeration for taste and odor removal.

Waring (24) has shown the relation between oxygen deficiency and earthy tastes. This condition is characteristic of the southwest surface waters. Aeration alone improves the condition only slightly, but in combination with filtration there is a decided change.

A series of experiments conducted at Forth Worth, Texas, a few years ago, demonstrated that at certain seasons coincident with tastes, the dissolved oxygen was as low as 47 per cent saturation. Aeration increased it to saturation or slightly over. While in practically all instances no tastes were noticeable at the plant, samples taken at some distance from the works showed taste, the intensity of which appeared to be proportional to the distance from the plant. The nitrogen cycle as measured by free and albuminoid ammonia and nitrites and nitrates was undisturbed. No change in taste could be traced to aeration alone although after filtration a decided improvement was noticed.

It has been demonstrated a number of times that no oxidation of organic matter takes place to any appreciable extent and that improvement is due solely to the sweeping out effect of the air.

It would be futile to expect any oxidation of organic matter without the presence of certain microörganisms. This has been repeatedly

demonstrated in the various experiments with sewage treatment by the activated sludge process. Assuming that the proper organisms are present there is still a time factor to consider. These may account in part for the results obtained by aeration followed by filtration.

A distinction should proably be made between odors and tastes of decomposition and those of growth. It would be expected that the former would yield quicker to the sweeping out effects than the latter. The experiences at Dallas, Texas appear to verify this. The water is from an impounded lake and there are taste and odor troubles in summer. The practice is to chlorinate the raw water with a dose of 0.90 to 1.20 p.p.m. and then aerate by means of vertical riser pipes discharging over steps.

Mr. O. M. Bakke, superintendent of the plants, reports as follows:

> I think most of the chlorine passes off during aeration. I have not the figures just after the water leaves the aerator, but by the time it leaves the mixing chamber there is only a trace and none when it leaves the settling basin. Before pre-chlorination we had very serious taste troubles that were not relieved by aeration. Judging by the odors given off at the aerator it must have lessened the taste slightly before chlorination was used, but nevertheless it was ineffective. I feel sure that chlorination is more effective than aeration.

TASTE REMOVAL

Beneficial effects have been noticed at Defiance, Ohio (30) where the water is recarbonated. Here the carbon dioxide gas mixed with some air is pumped into the filtered water. An improvement in taste is reported.

St. Paul, Minnesota reports improvement in taste and odors by aerating the water as it flows through the mixing chamber. An air diffusing pipe is laid in the bottom and air under 5 to 6 pounds pressure is applied at the rate of 6000 cubic feet per million gallons. The additional cost was 50 cents per million gallons.

The experiences of New York, Richmond and Danville, Virginia, and West Palm Beach, Florida have been mentioned by Donaldson. To this might be added a number of others all of whom report improvement, among them being Appleton, Wisconsin (25), Bloomington, Indiana (26) and a number of smaller plants.

At Whiting, Indiana, Hansen (28) found improvement in taste and odors caused by oil refinery wastes, but no improvement was noticed when phenol wastes were present.

Bartow (29) recommends aeration after chlorination to remove chlorination tastes.

AERATION AND BACTERIAL REDUCTION

At Tyler, Texas, 2 tests were made and they report 60 and 40 per cent respectively reduction in total bacteria due to aeration.

A series of 127 tests made daily beginning in August 17, 1922 and extending through to January 13, 1923 at Forth Worth, Texas showed a reduction of 35.6 per cent in total bacteria growing on agar at 37°C.

Several factors might be cited as being responsible for this, such as oxidation of the bacteria themselves, or mechanical destruction. The factor which we regard as contributing most is that of the bacteriacidal effect of the intense sunlight in this region.

AERATION IN TEXAS

A questionnaire was sent out to 54 water works superintendents in Texas, to which 30 replied. Of these 30 replies, 15 represented well supplies, 14 surface waters, and one a mixture of both. Of the 15 well supplies representing a population of 679,800, 12 report no taste or odor troubles. One supply serving 3200 has trouble with hydrogen sulphide, another representing 10,000 has iron trouble, and a third, Houston, reports occasional tastes attributed to iron bacteria. Aeration is resorted to in the treatment of the hydrogen sulphide and iron containing waters. Of the 14 surface supplies representing a population of 791,000, only one supply caring for 45,000 people reports freedom from taste and odors, while all the others report trouble coincident with hot weather or low water. The tastes are always reported as coming from algae. Of these 14 surface supplies, 8, representing a population of 597,000, report aeration in some form, 2 using spray nozzles, 5 using riser pipes and cascades, and one forcing air into the water by means of a paddle wheel. In all instances an improvement in taste and odor is indicated.

In the Treasury Department Water Supply Standard we find that they specify; "No odor of hydrogen sulphide, chlorine or other substances and the water should be free from odors caused by the presence of microscopic organisms,"—and that "Iron as Fe, should not exceed 0.3 p.p.m."

If these requirements are to be met there is no doubt that there will be a great many aerator installations in the future. As soon as the

public recognizes that tastes and odors can be eliminated, or at least reduced, by some method they will demand it.

The use of pre-chlorination or super-chlorination followed by aeration offers a great field of possibilities.

Another use of aeration is suggested in connection with swimming pools. It has been our experience that a $\frac{1}{2}$-inch pipe spraying water in the air over a pool, apparently satisfies the general public more than a 6-inch line discharging sterilized, filtered water beneath the surface.

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DISCUSSION

Philip Burgess: It is well known that in most instances aeration is a fundamental part of iron removal. The author called attention to the fact that catalytic action is required in order to get the iron in the proper form to precipitate. This can be combined with aeration very nicely by using an aerating tower of the type used in Germany for many years. The speaker has built two plants in Ohio where the well water used as a source of supply contains iron. Water from the wells is discharged over the top of horizontal trays, 12 inches deep, containing coarse granular material. It makes no difference what that material may be so long as it is somewhat porous. The trays are 12 inches deep and about the same distance apart. Passage of water through the trays causes both aeration and catalytic action. The latter occurs in the material as the water percolates through the trays. After passing through the trays, the water should be red. A settling basin has little, if any, value. A basin of small capacity has perhaps some value in the treatment to provide time necessary to complete the reactions started by passage through the aerator.

Mr. Koyl: I belong to one of the railroads, and I want to say a word concerning the action of free CO_2 in water as we experience it. I make no statements about municipal plants or stationary boilers in general, because I do not know much about them, but in the case of locomotive boilers we have had some definite experience.

Six or seven years ago we used to think CO_2 in water a dangerous article in the matter of corrosion, but when we put lime-soda water-treating plants on the road which extracted the CO_2 and reduced the mineral matter in the treated water to two grains per gallon of calcium carbonate, three or four grains of sodium hydroxide and various amounts of sodium sulphate and chloride, we found that this water which was entirely free of CO_2 pitted the boilers almost as much as it did before we put up the water-treating plants. That of itself settled for all time the question of the action of CO_2 as the main pitting producer in locomotive boilers.

Then we noticed up in Northern Montana where we had a water-treating plant at every water station, that the pitting with this treated water was confined to the front half of the boiler. Presumably the steel was of the same character from end to end of the boiler and was not changed by the temperature. The difference be-

tween front and back pitting was certainly not due to any weakening or electrolytic effect in the hot end of the boiler, because in that end the flues are surrounded in the flue-sheet by copper ferrules and the electromotive force between steel and copper is much greater than between any two pieces of steel. If difference of electric potential controlled the situation the flues in the back end of the boiler would not last a month.

But the water entered those boilers near the front end at the injector temperature of about 170°F., then mixed with the other front-end water at a temperature above 300° and slowly passed back to the firebox where it reached its final boiler temperature; and we soon found that during all this time it was losing its dissolved gases, of which the oxygen dissolved from the air is the only important one. Our immediate conclusion was that the oxygen dissolved in the water was the controlling factor in the cycle of operations which result in pitting, because the disappearance of oxygen from the water to the steam space was the only important difference we could find between conditions in the front half and the back half of the boiler.

Later we added to one of the boilers an open locomotive feedwater heater, attached to the outside of the boiler and so arranged that cold feedwater from the engine tender is delivered into the cast-iron chamber of the heater in a spray to meet there the exhaust steam from the engine cylinders, be raised to a temperature of about 215°, give up its dissolved gases to the little chimney, and then drop to the hot water pump which sends it to the boiler. Remember that when water is delivered in a spray into a stream of hot steam it is much easier to heat the drops and discharge the dissolved gases than it is when the water is in a mass like water in a barrel with a mechanical stirrer.

For comparison this locomotive has an exact mate, using the same water and doing the same work, but without a feed-water heat. With the heater engine we extract about 60 per cent of the free oxygen on the average, but 80 per cent when everything is going right. These boilers have been running two years in our worst pitting treated-water district. Every two months we take out a couple of flues from each. The feedwater boiler is still in good condition with scarcely a pit mark in her, but the companion boiler has lost about half her flues to the scrap heap because of pitting on the front half. There is very little on the back half.

The theory of the action of the oxygen is that when an atom of

iron from a flue dissolves in the water it releases on the cathodic surface an atom of hydrogen; that these atoms of hydrogen cling to the flue and soon form a film about the flue which protects it and stops the electrolytic current which is the primary cause of the pitting. Without oxygen in the water this film is permanent and pitting stops, but with oxygen in the water the hydrogen and the oxygen combine chemically, the protecting film is destroyed and pitting proceeds.

Compared with the power of this oxygen action, the effect of free CO_2 is infinitesimal and may be neglected.

WELLINGTON DONALDSON: Mr. Mahlie has covered his field so thoroughly that it would seem superfluous for me to take very much time in discussion. Of the various points which he has brought up the most interesting one to me is the bacterial removal and is one which is quite a novel feature. I think if anyone in whom I had less confidence than I have in Mr. Mahlie, had made that statement, I might have asked the court to recount the ballots, but when Mr. Mahlie gives these results of some 127 bacterial experiments on a series of samples, I am bound to believe this thing has happened down in Fort Worth. This is certainly a very interesting thing in connection with aeration. If these results can be confirmed elsewhere it would mean we have added to our kit of tools in the purification game another process which is quite useful in reducing bacterial loading.

Another interesting point brought out by Mr. Mahlie is the removal of chlorine by aeration. That would seem to extend the possibilities of water treatment somewhat, in allowing over treatment with chlorine and removal of the excess of chlorine before the water reaches the consumer. Just how far that method could be used remains to be seen. I recall that at Richmond, Virginia, when the new plant was put into service 3 years ago, tests were made on the aeration system, which consists of 300 spray nozzles, handling filtered water. I do not want to speak very much about those results because Mr. Baldwin of Richmond is here and his memory is better than mine, as he actually made the tests. I simply state that it was found that the spray aerators removed as much as 90 per cent of the chlorine added a few minutes before aeration.

There is one feature of aeration which has not been touched on and one which the late Professor Whipple was very fond of dwelling

upon and that is the aesthetic value of aerators. There is no doubt that to the average citizen aeration is one of the most attractive features of the water plant. Purification men accustomed to showing visitors about the plant will agree with me, if you have an attractive aerator, your plant visitors will spend most of their time around it while more important features of the plant go unnoticed.

I should like to mention also the value of aeration outside of the usual function of removing appreciable odors in the raw water or the filtered water. Those are clear cut cases where you have something definite in the water and where it is obvious that aeration is of value in improving the quality of the water. There are many other cases, however, where the water as delivered to consumers might be adjudged as of fair quality of filtered water and without any objectionable taste or odor. Yet in many instances aeration of that water does improve its palatability and make it more attractive, without changing chemical constituents in measurable quantities.

PREVENTION OF SUB-AQUEOUS CORROSION BY ELECTRO-CHEMICAL POLARIZATION PROCESS[1]

By O. W. Carrick[2]

To combat satisfactorily a problem of such complexity as the erratic corrosion of metals, it is first essential that some practical theory be promulgated for its cause. The slow but sure process of the scientists in unravelling the immutable laws of nature have brought us to our present state of understanding of the causes for this phenomenon, thus making it possible to apply the theories in an ameliorative manner. Therefore, as we in our limited way look into the future we can visualize a slow evolution from the present "Rusting Iron Age" to a "Rustless Iron Age," and we seem to be living in the transition period.

The two principal fields of corrosion are atmospheric and sub-aqueous or the disintegration of the metal when entirely or partly immersed in a liquid bath. For the former the use of protective coatings such as paints has helped, but due to the renewal expense and ever increasing limitations of its use and afforded protection, there has, within the last few years, been marked advance in the manufacture of non-corrodible metals.

To bring out the fact more clearly that protective coatings have their limitations, I quote a statement from a recent trade journal:

> At a conservative estimate, corrosion costs America alone a half a billion dollars a year. This figures in the industrial budget in the form of increased maintenance costs, curtailment of production incidental to the installation and repair of equipment, and very often loss of customers due to the rusting of machine parts in transit.

Production of non-corrodible metals is increasing at a rapid rate and today we have available for various uses, aluminum, copper, brass, bronze, nickel, lead, tin, silver, zinc and a large number of alloys such as duralumin, monel metal and duriron resulting from a

[1] Presented before the Illinois Section meeting, March 30, 1928.

[2] Water engineer, Wabash Railway Company, Decatur, Illinois.

combination of some of these, or with iron, steel, chromium, manganese, silicon, etc. However, none of these metals have the universal attributes of iron and steel, in that they are either more expensive or do not give satisfactory service, or both. Thus, this is still a good field for the research man.

On turning to under-water corrosion we soon find that the problem becomes more involved and that protective coatings are difficult to maintain and sometimes accelerate the corrosion. It was always noticed that absolutely dry iron did not corrode and that the rate of corrosion was affected by the amount and quality of moisture surrounding it, also that the flow of an electric current from it to the liquid had marked effect upon the rapidity of destruction. In 1883 the celebrated English scientist, Michael Faraday, expounded his first law of electrolysis as follows: "The quantities of substances set free at the electrodes are directly proportional to the quantity of electricity which passes through the solution." Shortly afterwards he made a little more definite statement in his second law which says that "The same quantity of electricity sets free the same number of equivalents of substances at the electrodes." Thus the quantity of iron liberated at the anode during the passage of two amperes of electricity through a solution is double that removed when one ampere passes through the solution. This led to the development of the table of electro-chemical equivalents for the elements and the finding that 26.8 ampere-hours deposit 1 gram—equivalent of any substance.

In the water works field you are familiar with the deleterious effects of electrolysis produced by stray or thermal currents and frequently you are able to estimate fairly close the magnitude of the current flowing.

However, this did not entirely explain the corrosion of iron when there was no apparent flow of current, and in 1903 W. R. Whitney presented his classic work on the theory of electrolytic corrosion (J. Am. Chem. Soc., 25, 394). He pointed out that,

Practically the only factor which limits the life of the iron is oxidation, under which are included all the chemical process whereby the iron is corroded, eaten away or rusted. In undergoing this change, the iron always passes through or into solution, and as we have no evidence of iron going into aqueous solution except in the form of ions (electrically charged atoms), we have really to consider the effects of conditions upon the potential difference between iron and its surroundings. The whole subject of corrosion of iron

is therefore an electro-chemical one, and the rate of corrosion is simply a function of electromotive force and resistance of circuit. The velocity with which the process proceeds will depend on the temperature and on the hydrogen ion concentration of the water, etc.

With the view of arriving at more absolute values for those postulated by Dr. Whitney, many investigators have been doing work in line with his theory and in substance it is still held to be good. Nevertheless, there is yet some dissension in the research ranks, but when you perceive the influence that a dozen or more factors have upon the rate of corrosion, you will understand the possibility of erroneous conclusions. Some of these factors are, solution pressure of the metallic iron, hydrogen overvoltage, hydrogen ion concentration, velocity of flow, temperature, density, catalytic agents, oxygen, character of protective films, current density, passivating agents, metallic salts in solution, etc. These, as I have stated, control the rate of corrosion, but the basic cause for this phenomenon is the tendency of the iron to dissolve known as its solution pressure and the exchange of the positive charge carried by the hydrogen ion to the iron atom producing a soluble ferrous ion and monatomic hydrogen as illustrated in the chemical equation.

(1)	Fe	+	2H	→	Fe	+	2H
	Metallic Iron		Ionic Hydrogen		Ionic Iron		Monatomic Hydrogen

This is the principal of the galvanic or voltaic cell and means that chemical energy is transformed into electrical energy and the electromotive force produced will be influenced by the difference of potential between the anode and the cathode pole and the hydrogen ion concentration or pH value of the liquid or electrolyte. The hydrogen leaves the solution at the cathode and plates out as a gaseous protective film. If it remains the cathode potential will be raised to that of the anode where the iron went into solution, thus producing an equilibrium and no current flow. The reaction will cease if the hydrogen film is not removed by oxidation to form water or by its evolution as a gas due to the voltage pressure being greater than the polarization pressure or by physical means. For many industries the polarizing effects of the hydrogen film is very undesirable, but you can readily see that it is most desirable for the protective film to be maintained in order to prevent iron from going into solution.

In the foregoing the two basic causes for corrosion of iron are given,

namely that type produced by electrolysis and that resulting from local galvanic action. The former is due to electrical currents generated by some external force passing from the iron to the water and the latter is due to electrically different parts of the iron caused by heterogenity and various other influences. With this in mind one can readily see that a system for the prevention of corrosion must in some way or other effectively counteract these two main types of current flow.

ELECTRO-CHEMICAL POLARIZATION SYSTEM

In the development stages of the electro-chemical polarization system as applied to locomotives, these fundamentals were given every consideration as well as the various factors that affect the rate of destruction. In this age of specialization, it so happens that the system has been developed in the locomotive field. A water works man no doubt is indirectly, if not directly, interested in the effects the millions of gallons of water he supplies the locomotives has upon the boiler parts and general locomotive operation.

If he is furnishing an undesirable water he probably has received complaints to this effect. These complaints, whether due to the incrusting, foaming or corrosive quality of the water, occasionally are quite an influential factor in justifying a change of supply or method of treatment or both. In the matter of corrosion he may not have as yet been cognizant of the fact that the water is causing pitting or grooving, or general corrosion, thus requiring the scrapping of large portions of the locomotive boilers at frequent intervals. It is possible that as our knowledge of the mechanism of corrosion increases, as it surely will, these complaints will become stronger and justifiably so, for the chemical composition of the water has a very marked influence on the rate of destruction.

There are in the United States alone, about 72,600 locomotives, 61,000 of which are operating on what is known as Class 1 railways and it is conservatively estimated that from \$12,000,000 to \$15,000,000 are spent annually for repairs to pitted and corroded boilers. The type and location of the corrosion varies considerably, but pitting and grooving are the most destructive no matter where they take place.

At Bloomington, Illinois, the Chicago and Alton switch engines using city water, the poor quality of which you are all familiar with, begin to have flue failures through pits in as short a period as nine

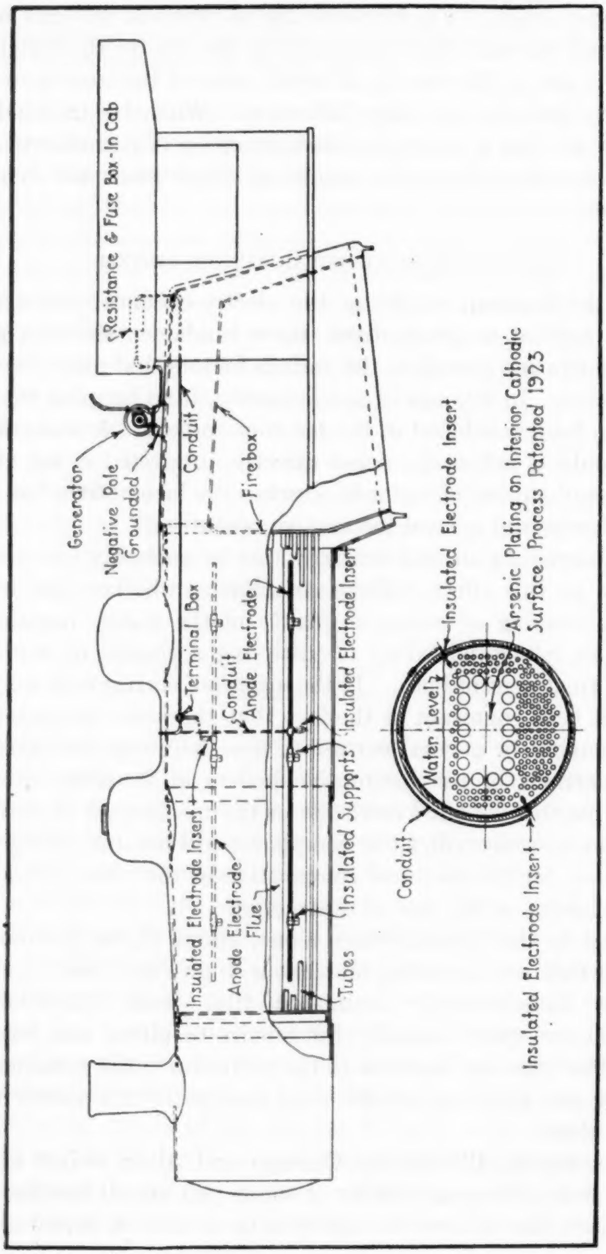

FIG. 1. ELECTRO CHEMICAL POLARIZATION SYSTEM FOR THE PREVENTION OF PITTING AND CORROSION

months after flue application. Upon shopping it is frequently necessary to discard from $200 to $1500 worth of pitted flues and may be the entire firebox, bringing the total corrosion damage up to from $2500 to $4000 per shopping.

This is an ideal place to test the effectiveness of an anti-corrosion scheme and in October 1924 one Polarization system was installed in one of the Bloomington yard engines and one in a C & A passenger engine under the supervision of Mr. L. O. Gunderson, chemical engineer for the road.

These original test installations gave immediate protection against the corrosion of the boiler interior and only slight changes have been made up to the present time. The workings of this system of protection can be best described by referring to figure 1.

From this you will see that the positive pole of the headlight generator is connected to resistance coils and fuses located in a metal box on the interior of the locomotive cab and from this box the connecting wire runs to two electrodes protruding through the boiler shell at points diagonally opposite each other. These electrodes are securely connected to two thoroughly insulated and rigidly clamped iron pipe anodes, both of which are at all times below the surface of the boiler water. The negative pole of the generator is grounded to the boiler shell, thus causing the direct current to flow through the resistors to the anodes, and from the anodes through the boiler water to the water immersed portions of the boiler and back to the negative pole of the generator thus completing the circuit. The resistance units are made to provide approximately 2 volts and from 2 to 3 amperes to each electrode, giving about 2 milliamperes per square foot of protected surface.

The imposed current functions to eliminate any electrolysis currents that might originate externally or be set up by thermal differences in the boiler, but since the greatest amount of corrosion is due to galvanic action the fundamental work of the imposed current is to maintain, in conjunction with an arsenic plating, a protective film of hydrogen on the cathodic surfaces of the boiler. As previously stated, the destructive currents set up by electrolysis are different than those produced by the differences of potential in the metal caused by various conditions such as impurities or grain stress, giving rise to the local galvanic couples, consequently, two different methods must be used for their elimination.

It can be demonstrated experimentally in the laboratory that a

metallic body acting as a cathode in an electric circuit does not stop local galvanic couples from functioning at any point or points on its surface. (Railway Review, Sept. 4, 1926).

U. R. Evans in his book "Corrosion of Metals" 1924, page 186, also brings out this fact in the following:

> It should, however, be stated that to prevent misunderstanding, that there is no fundamental reason why corrosion should necessarily cease when a metallic article is functioning as a whole as a cathode since local currents may still be flowing between different parts of the surface.

Mr. Speller in his researches has found this same condition to exist and in his book "Corrosion: Cause and Prevention," 1926, page 433, says,

> Local electro-chemical action will continue on a surface which is within the protective influence of an externally applied current. It is, therefore, unsafe to rely too much on electrolytic protection without taking other precautions.

One of the reasons for using arsenic instead of any other metal is due to the ease with which it can be plated upon iron, in fact it will plate out by immersion and in this respect is similar to copper, but the most important reason for its use is due to the high discharge potential it has when hydrogen is plated upon it. This rapidly causes polarization of the galvanic couples set up upon the metal surfaces and due to the function of the countercurrent supplying an excess of hydrogen to react with the oxygen or other oxidizing agents entering the boiler, the protective hydrogen film will be undisturbed. The arsenic plating alone would not prevent corrosion, if there were any oxidizing agents present to remove the hydrogen film, thus disturbing the equilibrium set up by its polarizing effects.

Again referring to figure 1, you will see that the iron pipe anodes extend for almost the entire length of the flues, thus with low voltage good distribution of current is insured throughout the boiler. Only enough current is required to plate out sufficient hydrogen to maintain the polarization of the arsenic plated cathode areas, and supply an excess amount of nascent hydrogen at the boiler metal surface to reduce chemically any oxygen which may diffuse through to the metal surface. The arsenic plating is maintained by adding an arsenic salt to the boiler in amounts varying from 2 to 4 pounds per month. The system requires that the imposed direct current be supplied to

the electrodes at all times the locomotive is in service, so as to maintain enough excess hydrogen to react with the oxidizing agents entering with the boiler feed water.

The additional load on the generator amounts to approximately 125 watts, which will cost in steam consumption, when generator is run for lighting purposes, only about $\frac{1}{2}$ cent per hour, and when generator is run to supply the current only to the anodes, the cost will be about 2 cents per hour. In order to eliminate the use of the

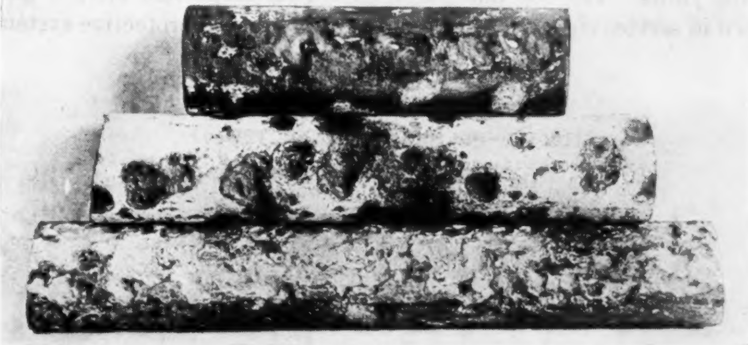

FIG. 2. BADLY PITTED AND CORRODED FLUES FROM BLOOMINGTON SWITCH ENGINE 44 IN CONTEMPORARY SERVICE TO ENGINE 49 BUT NOT EQUIPPED WITH ELECTRO-CHEMICAL POLARIZATION SYSTEM

Historicity of flues in engine 44

December, 1926, flues reset		December 21, 1927, 1 flue	Burst through pit and renewed
September 9, 1927, 1 flue	Burst through pit and renewed	January 5, 1928, 2 flues	
October 19, 1927, 1 flue		January 10, 1928, 7 flues	
December 1, 1927, 1 flue		January 17, 1928, 5 flues	
December 9, 1927, 7 flues			

generator during daylight hours to prevent the higher cost of steam consumption, an electric storage battery is installed wired in series with the lighting circuit. The relative simplicity and low initial, operating and maintenance cost for the system makes it a very economical installation.

Figure 2 shows pitted flues that have been removed from a switch engine that is not equipped with the Electro-Chemical Polarization System, operating in the yards at Bloomington, Ill. You will note

the excessive pitting. This engine received a set of flues in December 1926, and after only nine months service it became necessary to begin replacing flues that had failed on account of pitting. To date after only fifteen and one-half months service over 100 pitted flues have been renewed on account of failing in service. A contemporary engine equipped with the Electro-Chemical Polarization process has operated in these yards for nearly four years without any signs of pitting.

Figure 3 shows flues removed from a switch engine working in the same yards. The top flue was removed for inspection after it had been in service eighteen months after applying the protective system

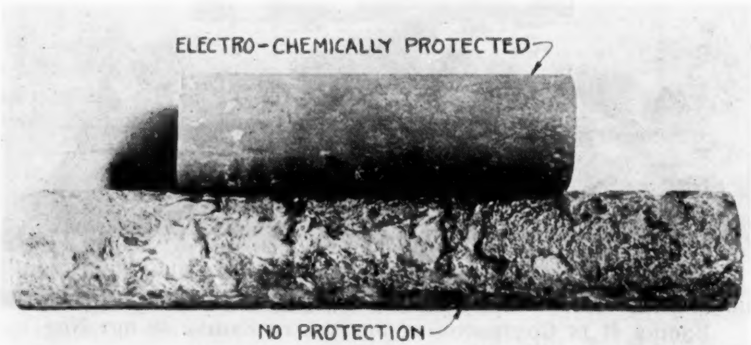

FIG. 3. TOP FLUE AFTER 18 MONTHS IN BLOOMINGTON, ILL. SWITCH ENGINE 49 EQUIPPED WITH ELECTRO-CHEMICAL POLARIZATION SYSTEM

Bottom flue after 18 months in same engine 49 before using the system

and you may see that it is in first class condition. The bottom flue shows the excessive corrosion that had taken place for the same length of time previous to the installation.

For three and one-half years the Electro-Chemical Polarization Process has functioned to prevent corrosion in locomotive boilers, which is severe service for any kind of equipment. There has been practically no maintenance expense. The cheap anode pipes disintegrate, but last from three to four years and are, in a manner, sacrificed to protect the boiler metal. The process is being applied to all Chicago & Alton Railroad Company's locomotives. Installa-

tions have been made on the Wabash Railway, on a road in Texas, and on a road operating through Nebraska and Wyoming.

There is a corrosion problem in the water works field and there is good reason to believe that it can be materially reduced by a slight modification of the process as applied to a locomotive. At any rate, it is hoped that the data presented will be responsible for some constructive thinking along this method of attack.

THE EFFECT OF CERTAIN ILLINOIS WATERS ON LEAD[1]

By O. W. Rees[2] and A. L. Elder[3]

The question of the solubility of lead in water and its toxicity is by no means new. Although lead poisoning from water supplies is not restricted to any definite locality, most of the cases cited in the literature have been from supplies characterized by low mineral content. Since the water supplies in Illinois have relatively high mineral content, cases of lead poisoning here are uncommon. Our interest in this subject has been recently aroused by the appearance of a peculiar case in Champaign, diagnosed by physicians at Mayo Brothers' clinic, as lead poisoning. The patient had some of the characteristic symptoms of lead poisoning and was found to be excreting approximately 0.1 mgm. of lead per day. After all possible sources of lead aside from the water supply were supposed to have been thoroughly examined, an analysis of the water supply for lead was requested. The result showed 0.08 p.p.m. of lead present. From information which we have obtained there appeared to be some lead pipe between the city main and the tap in the patient's house.

Cases are on record of waters which contain lead as pumped from the ground, but the chief source of lead in water is from lead pipes which have been used for carrying water for centuries. Records at Rome indicate that lead pipes were installed there about 20 A. D. and have been in use since that time. From a table recently compiled by Donaldson (2) it appears that lead pipes are in use all over the United States. Lead poisoning must be considered a possibility wherever lead pipes are used, although certain factors to be mentioned later make it highly improbable in many instances.

One of the first clear cut cases of lead poisoning cited in the literature is that of Louis Phillipe who settled with his family at Claremont, England (3) in 1848. The water was brought from a spring two miles distant through lead pipe. For thirty-three years the

[1] Presented before the Illinois Section meeting, March 29, 1928.

[2] Chemist, State Water Survey Division, Urbana, Ill.

[3] Chemistry Department, University of Illinois, Urbana, Ill.

water was used with no ill effects but when the spring was covered in such a way as to prevent the escape of carbon dioxide, 34 per cent of the users of this water were poisoned. Hamilton (4) cites the case of the poisoning of nuns in a convent near Lyons which was discovered by Lacour after three of the nuns had died and when twelve were still living but still seriously affected. For ten years the nuns had been drinking a water containing 2.7 mgm. of lead per liter. Since 1870 many cases of lead poisoning have been found in New England (5). Best known are those in Massachusetts, particularly that of the Lowell outbreak in which 41 cases were reported. Cases of lead poisoning at Milford, Fairhaven, Kingston, Norwood,

TABLE 1

Allowable limits of lead in water

DATE	AUTHOR	LEAD
		p. p. m.
1886	Watkins (1)	1.7
1895	Whitelegge (21)	1.0
1910	Gärtner and Telekey (3)	1.0
1917	Barbour (32)	0.5
1923	Howard (6)	0.5
1925*	Thresh (34)	0.5
1920*	Weston (2)	0.1
1924	Whipple (7)	0.1
1925	Manual A. W. W. A. (8)	0.1

* Thresh and Weston cite many other authors. Limits vary from trace to 1.43.

Gilbertsville, New Bradford, and Hopedale, Mass., Atlantic City, N. J., and cases in Rhode Island, and New Hampshire may be mentioned.

In the above cases it appears that different amounts of lead in the waters were responsible for the poisoning. With nearly every report of a case of lead poisoning one finds a different figure given for the maximum amount of lead allowable in a water supply. Table 1 gives a list of some of the allowable limits cited with the author and date at which the statement was made. From the variations in the table it is not at all suprising that lead pipes are often accused of being responsible for lead poisoning. Many authors believe that any detectable trace of lead in a water supply should be looked upon

with suspicion, while others point out that many water supplies always contain some lead.

As individuals vary greatly in their susceptibility to lead poisoning it will be very difficult to give a limit which will be satisfactory. Thresh cites one case of lead poisoning where only 0.0466 p.p.m. of lead was found in the water. He questioned the validity of this case as it was lower than any other figure which he had. The sample submitted for analysis may or may not have been a fair sample of the supply. Whipple summarized the information regarding limits quite well when he stated that ten to twenty years ago he would have placed the limit at 0.3 to 0.5 p.p.m. while now he places it at 0.1 p.p.m.

TABLE 2

Causes of lead erosion	*Causes of lead solvency*
Low alkalinity < 15 p.p.m.	Free carbon dioxide
	Humic, and peaty acids
High dissolved oxygen	Mineral acids
Salts-NaCl, etc.	

TABLE 3

Water causing solution of lead

SOURCE OF SUPPLY	HARDNESS	ALKALINITY	CARBON DIOXIDE
	p. p. m.	*p. p. m.*	*p. p. m.*
Cook well at Lowell	55	33	45
42 wells (Thresh)	7.3–90	0–75	1.0–5.5
Milford-Hopedale	24	27	1.4
Canal Zone		0.6–4.2	

As there is such a variation of opinion as to the limit, considerable weight should be given to the figure of 0.1 p.p.m. given in the Manual of Water Works Practice (8).

The important factors causing the solution of lead appear to be high carbon dioxide, organic acids, oxygen, low alkalinity and possibly nitrates, nitrites, and chlorides (1, 6, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 5, 2, 21, 22, 23, 24, 25, 26, 27, 28, 30, 31, 32, 33). The actions of water on lead according to Weston (3) can be classified into two groups (*a*) plumbo-solvency which is the true solution of lead and which usually takes place in the presence of carbon dioxide and other acids, and (*b*) erosive action caused by slightly alkaline waters containing dissolved oxygen.

Donaldson (2) agreeing with Weston defines erosion or "lead rusting" as the term used to describe the action of neutral or slightly alkaline oxygenated waters on lead. Solvency or plumbo-solvency is used to described the action on lead of highly carbonated acid waters, which may or may not contain oxygen. Baylis (33) thinks that the compound formed in the presence of much carbon dioxide may be a basic carbonate of lead $Pb_3(OH)_2(CO_3)_2$. Table 2 summarizes the important causes of lead erosion and plumbo-solvency.

The hardness, alkalinity and CO_2 of some waters known to have caused lead poisoning are given in table 3.

TABLE 4

Public ground water supplies in Illinois and their residues

NUMBER OF SUPPLIES	RESIDUE
	p. p. m.
0	0–100
0	100–200
35	200–300
111	300–400
68	400–500
62	500–600
35	600–700
29	700–800
16	800–900
11	900–1,000
41	1,000–1,500
27	1,500–2,000
24	Over 2,000

In order to show the differences between the supplies noted in table 3 and Illinois supplies, a number of ground waters analyzed by the State Water Survey are listed against the residue in p.p.m. One notes from table 4 that there is not a ground water supply in Illinois which has been listed in State Water Survey Bull. 21 (35) which has a residue of less than 200 p.p.m.

Most Illinois waters are so highly mineralized that an analyst has considerable difficulty in separating the trace of lead present from the large amount of residue obtained on evaporation.

ANALYTICAL DETERMINATION OF LEAD

Several different methods have been used in determining lead in water. H. Pick (36) removed minute quantities of lead by adsorp-

tion on asbestos. The asbestos was filtered off, and the lead dissolved and determined. B. Avery (37) and others concentrated the water to a small volume, precipitated the lead as the sulfide, dissolved this in nitric acid, precipitated the lead as the sulfate, dissolved this in ammonium acetate and finally precipitated it in Nessler tubes as the sulfide. Another method was that of spectroscopic analysis as suggested by Lewis (38). He claimed that this method could be used to determine traces of lead in water. His method was tried out in this work and was found to be unsatisfactory. To determine successfully very small quantities of lead in water, large amounts of the water must be evaporated. In a region like this where the waters have, for the most part, comparatively high residues, one is forced to handle rather large quantities of material and this is mechanically almost impossible. Another difficulty with the method is that iron, which is nearly always present in greater quantities than the lead, gives a multitude of lines in the spectroscope which makes it quite difficult to detect the line produced by lead. The lead line persists only a short time and photographic plates are almost essential to detect it.

For the most part colorimetric methods have been used in the determination of lead in which the lead is precipitated as the sulfide and compared to standards. Different modifications of this general method have been used. Von C. Reese (39) and Drost devised a modification to take care of error introduced into the general method by organic matter. They used a sample of water in question, from which all lead has been removed for making up standards. According to Thresh (29) the presence of traces of copper such as are likely to be present in distilled and in many natural waters often interferes with the colorimetric determination of lead as the sulfide. He recommended the addition of 2 cc. of the following solution before the addition of the hydrogen sulfide: 30 cc. British Pharmacopoeia acetic acid, 70 cc. copper free distilled water and 0.1 gram "gold leaf" gelatin.

The method for determining lead in this work was that given in Standard Methods of Water Analysis (17). It consists essentially in concentrating the sample, precipitation as the sulfide, solution in nitric acid, precipitation as the sulfate in 50 per cent alcohol, solution in ammonium acetate, treatment with hydrogen sulfide and comparison with standards containing known amounts of lead. This method was designed for use in determining lead in low residue

waters and so has its objection when used on high residue Illinois waters. However, it appears to be the best method available at the present time.

EFFECT OF ILLINOIS WATERS ON LEAD

Using the method just outlined, analyses of water were made from the sources shown in table 5. There appears to be some solution of lead from a water such as the Champaign-Urbana water.

A brief investigation of waters of equivalent alkalinity to Champaign-Urbana water but containing varying concentrations of NaCl was made. NaCl was used because statements were found in the literature regarding its producing increased corrosion and because the chloride content of some Illinois waters is high. Chlorides could

TABLE 5

Lead in water

SOURCE	LEAD
	p. p. m.
Patient's home	0.08
Patient's home	0.08
House next door	0.03
Tap A	0.05
Tap B.*	0.09
University tap	0.02
Distilled water	0.01
Pontiac, Ill.†	0.027

* 125 feet lead pipe connection.

† Surface supply. Raw water.

not be used to explain the solubility of lead in Champaign-Urbana water as there are only 4 p.p.m. of chloride present. Carbon dioxide (about 30 p.p.m.) and oxygen are probably the important factors here. Table 6 summarizes the result of this investigation. A white precipitate showed definitely in samples III and IV within twenty-four hours, II showed a slight precipitate in forty-eight hours. At the close of the experiment, six weeks later, samples II, III, IV, showed a turbidity of over 100 when thoroughly shaken. I, Ia never showed more than a trace of corrosion on the plate.

From these experiments it appears that sodium chloride is of importance in the corrosion of lead, but of little importance in the solution of lead.

So little is known regarding the solution of lead in Illinois waters that it was decided to place strips of lead in samples of water obtained from several city supplies. The strips were weighed, and then hung in bottles by string, and the bottles stoppered and sealed with paraffin. At the end of two weeks the samples were analyzed for lead in solution and the strips of lead were cleaned and re-weighed.

TABLE 6

Effect of varying the concentration of sodium chloride on the solubility of lead

SAMPLE	LEAD AT END OF SIX WEEKS		Distilled water	Solution $NaHCO_3$ AS $CaCO_3$	NaCl
	Suspension	Solution			
	p.p.m.	*p.p.m.*	*cc.*	*p.p.m.*	*p.p.m.*
I	0	0.3	1,000	400	0
I a	70	0.08	1,000	400	500
II	340	1.0	1,000	400	2,000
III	630	0.16	1,000	400	5,000
IV	510	0.45	1,000	400	10,000

Each bottle contained a strip of lead $\frac{1}{8}$ by 1 by 6 inches.

TABLE 7

Solution of lead in Illinois waters

SAMPLE	HARDNESS	ALKALINITY	CHLORIDE	RESIDUE	LEAD SOLUTION	LOSS OF WEIGHT OF LEAD STRIPS
	p.p.m.	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*mgm.*
Decatur	121	160	2	302	0.11	58.8
Cedar Point	222	150	295	1,009	0.025	46.2
Stronghurst	1,100	216	259	2,971	0.23	16.0
Danforth	156	290	530	1,374	0.2	88.7
Chenoa	240	304	550	1,276	0.5	66.0
Norris	110	542	1,010	2,743	0.43	25.8
Mt. Sterling	725	379	1,310	4,076	0.2	31.4

Table 7 gives the results of the analyses together with the alkalinity, hardness, residue and chlorides of seven samples of water.

From the data in table 7 it appears that there is no direct correlation between hardness, alkalinity, chlorides, residue and the effect of these waters on lead. We have noted that such erosion as takes place stops in a few days and if the strips which have been placed in the waters listed in table 7 and allowed to stand for two weeks are

placed in fresh samples of similar waters, the corrosion is negligible; indicating that these waters form protective coatings.

Studies on the prevention of corrosion of lead as cited in the literature indicate that one could expect little corrosion of lead by hard waters. The report of D. H. Stacks on "The Effect of Artesian Water upon Galvanized Steel Pipes" read before this organization in 1913 is the only authentic report of metal poisoning from water reported in this State of which we are aware. These cases were supposed to be due to zinc poisoning and all trouble ceased with elimination of the galvanized pipe.

PREVENTION OF LEAD CORROSION

The methods for preventing corrosion of lead have been studied for a long time and appear to be well known. Watkins (1) cites the inhibiting effect of silicates in the Mississippi river water on the solubility of lead. Clark (22) states that increase in hardness or addition of sodium silicates prevent the action of water on lead. Whipple (28) states that three-quarters of the water supplies in New England have a hardness of less than 20 p.p.m. The addition of lime to decrease the carbon dioxide content and increase the hardness of the waters prevents their action on lead. At Lowell, Mass., (32) it was found that aeration of the water to decrease the carbon dioxide from 45 to 3.3 p.p.m. reduced the lead content of the water to less than 0.5 p.p.m. At Deventer (9) it was found that the lead content of the water increased after the installation of an iron removal plant. Addition of lime lowered the lead content of the water from 0.6 to 0.2 p.p.m. Bunker (31) working with waters in the canal zone found that he must keep the alkalinity above 2.4 p.p.m. with that water to prevent over 0.1 p.p.m. of lead from going into solution. Addition of lime to the Birmingham (10) supply prevented trouble from lead poisoning. Thresh (26, 27) states that alkali silicates are several times more powerful than silicic acid in preventing solution of lead in water. Donaldson (23) cites a case in South Carolina in which soda ash was added to the supply to prevent corrosion. The addition of soda ash neutralizes acidity due to carbon dioxide and does not harden the water. At Keighley, England (9) sodium carbonate was added to the water before filtration to prevent plumbo-solvency. Baylis (33) states that the pH of 7.0 to 9.5 is least inducive to lead corrosion.

Whether any of our Illinois waters which may be softened and recarbonated will dissolve appreciable quantities of lead is yet to be known.

SUMMARY

The quantity of lead found in the Champaign-Urbana water was less than the allowable limit given in the Manual of Water Works Practice and also less than the quantity usually associated with lead poisoning. If poisoned from the water supply the individual poisoned by the Champaign-Urbana water must have been extremely sensitive to traces of lead.

The erosion of lead in waters containing $NaHCO_3$ alkalinity of 400 p.p.m. and varying NaCl content was found to increase with increase in the concentration of NaCl.

Analyses of average Illinois waters in which strips of lead were placed indicates that a protective layer soon forms which practically eliminates further corrosion of lead.

The procedure given in the Standard Methods of Water Analyses for the analysis of lead is not satisfactory for high residue waters.

It is to be predicted or at least to be hoped that, in the future, experiments on the solubility of lead, copper, and zinc in many different water supplies will be made, and that these experiments will be carried out in closed systems under conditions so that the factors of carbon dioxide and oxygen may be carefully controlled.

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THE USE OF URANINE DYE IN TRACING UNDERGROUND WATERS[1]

By A. W. Crouch[2]

In connection with some recent work at the Great Falls Plant, located near Rock Island, Tennessee, it was necessary to locate the outlet of a small sinking creek lying some 8 miles northeast of the plant. After a study of the whole situation and some ineffective tests with potassium permanganate several tests were made using uranine dye. This dye was found very effective in tracing underground water.

Sinking Creek emerges from the ground at the foot of a low mountain ridge about 2 miles north of the town of Doyle. It flows on the surface of the ground in a southeasterly direction for about three-quarters of a mile and sinks in an irregular row of small holes along the foot of a limestone bluff.

The rock formation in this section of the country consists of Bangor limestone with a dip to the east of 30 feet or less to the mile. The beds of rock vary in thickness from a few inches to many feet with numerous clay seams and clay pockets scattered throughout the area. Caves, underground streams, sink holes and springs are very common over the entire section. The Calfkiller River, flowing south, is about 3 miles east of the sink hole in which the dye was placed while the Caney Fork River, flowing west, is about 5 miles south of the sink hole. There are many springs of various sizes along the banks of both rivers.

A rather definite line of sink holes and caves extends from the point where Sinking Creek disappears to a point on Calfkiller River known as Hensley's Spring. By air course it is $2\frac{1}{2}$ miles away. Taking this fact into consideration together with the fact that the rock dips to the east it seemed probable that the Hensley Spring was the

[1] Presented before the Kentucky-Tennessee Section meeting, January 19, 1928.

[2] Resident Engineer, the Tennessee Electric Power Co., McMinnville, Tenn.

outlet for Sinking Creek, although later developments proved that this was not the case.

Uranine dye is a coal tar product. It is one of the numerous compounds derived from resorcin. The latter is made by fusing gum resins with caustic potash. Uranine is a reddish brown powder, which when dissolved in water, turns the water green. It is particularly adapted for coloring large volumes of water as it is easy to handle, readily soluble, safe and may be detected when present in very small quantities. From some rough tests made in the laboratory it was easily seen when present to the extent of one part in five million. It can be detected when present as one part in ten million. When present in small quantities it is most easily seen by placing some of the water with the dye in it in a test tube and hooding it so that the light strikes the side of the tube.

All the tests were made during the month of October, 1927. The stream flow in Sinking Creek at the point where it sinks was 1.4 c.f.s. at the time of the tests. No appreciable amount of rain had fallen for several weeks. As stated above it was expected that the outlet would be found along the Calfkiller River and it seemed reasonable to suppose that it would not take over one or two days to get results.

One and one-half pounds of dye were dissolved in water in large tubs and dumped into the creek at the sink holes in the first test. At the end of the second day no trace of the dye had been found at any of the springs along either river. Another pound of dye was then poured directly into the sink holes without first dissolving it in water.

On the morning of the fifth day after the first batch had been put in Sinking Creek green water was found at the Johnson spring located $3\frac{1}{2}$ miles southeast of the point where Sinking Creek disappears. The stream flow at this spring was 2.7 c.f.s. By night-fall all trace of the uranine had passed. Two days later or five days after the second batch of dye had been put in the creek green water was again noticed at the Johnson spring. As in the first case all the colored water had passed by dark. Judging by the strength of the color in the early morning it is probable that the uranine was first present at the Johnson spring some time during the night preceding. This spring is 71 feet below the level at which Sinking Creek disappears.

A third test was made two weeks after the first two under similar weather and stream flow conditions. In this test a glass jar was placed in the middle of the stream 15 feet above the sink holes. At

the start of the test 1 ounce of uranine was dissolved in water and poured directly into the creek. A continuous stream of water containing the dye was then discharged into the stream from the glass jar through a glass siphon at the rate of 1 ounce per hour dissolved in 2 or 3 gallons of water. Every half hour an extra heavy dose was poured in the creek. After continuing in this way for four and one-half hours another ounce of uranine was poured directly into the creek. A total of 8 ounces of uranine were used in this test. The dye was well mixed with the creek water before it sank to insure a more uniform distribution of the color. It was also thought that all the small sink holes might not discharge into the same channel underground.

On the morning of the fifth day after the dye had been put in Sinking Creek green water appeared at the Johnson spring. The color was the brightest on the afternoon of that day and could be seen up until late in the afternoon of the following day. Colored water was also found in a well at Onward $4\frac{1}{2}$ miles southwest of the sink holes. This well is fed by an underground stream, the bed of which is about 6 feet lower than the place where the uranine was introduced. On the sixth day the water from Reno spring, 5 miles south of the sink holes and on the banks of Caney Fork River, was green up until about 11 o'clock. This spring had a discharge of about 1 c.f.s. and is 87 feet lower than the sink holes where the dye was introduced. It has been reported but never verified that green water was also seen at a small spring one mile west of Reno.

Preliminary investigations indicated that the outlet of Sinking Creek would be found along the Calfkiller River. The outlet at Johnson's spring was in line with this reasoning. The outlet at Reno was a surprise. It is evident that a study of the rock formation and general topography of the country will prove helpful in locating the probable direction that an underground stream will take, but such a study should not be relied on entirely. Close watch should be maintained at all springs in the neighborhood.

Measurements of the stream flow should be made at both the point where the stream sinks and at possible outlets in order that proper quantities of uranine may be put in the water. Allowances should be made for the many uncertainties that are sure to be encountered.

It appears to be advantageous to put the uranine in the stream to be traced in small quantities over a long period rather than to dump the whole batch of dye in at one time. The advantage lies not

merely in the fact that the color is retained in the water longer but that it gives the observer time to get from one spring to another throughout the territory before the effect of the dye has passed.

The above tests show clearly that the results of a single test should not be accepted as conclusive proof that certain conditions exist. Of course, the method of introducing the dye is important, but at the same time it should be kept in mind that the stage of the water in the underground streams will have an appreciable effect on the results. This stage changes from time to time as does the stage of surface streams. At certain levels water will flow through cross channels while at other times it will be so low that the cross channels are dry. If the tests are being made in a stream which furnishes drinking water it would be well to make several experiments under various conditions.

Inasmuch as it is not usually possible to learn all about the bed of the underground stream it is almost impossible to predict the time that it will take the dye color to travel any given distance. In the experiments at Doyle the time interval was much longer than had been anticipated. Long quiet pools, falls, choked portions of the channel and the meanderings of the stream are more or less unknown factors to be reckoned with.

Taking all factors into consideration uranine is a very satisfactory dye to use in tracing underground water. It is easy to handle, it is easily detected and is not harmful to public health if it should get into wells in small quantities.

The author, before closing, wishes to acknowledge the many helpful suggestions made by Messrs. Fullerton, Morton and Clark of the Division of Sanitary Engineering of the State Department of Health, in connection with the above tests.

INTERFERENCE OF CLOSTRIDIUM WELCHII WITH BACT. COLI TESTS IN WATER ANALYSIS

By John F. Norton[1] and Marion Barnes[1]

We have attempted by pure culture experiments here recorded to throw some light on the possible interference by Clostridium welchii on the tests for the coli-aerogenes group in routine water examination.

Several strains of Clostridium welchii and of Bact. coli were used. The test medium was the standard lactose broth. In this medium Clostridium welchii in pure culture produced gas and acidities of pH 4.5 to 4.8 in twenty-four hours and pH 4.2 to 4.5 in forty-eight hours. Extended incubation did not further increase the acidity. In most instances the organisms had ceased to be viable at the end of forty-eight hours. The strains of Bact. coli used produced gas and acidities of pH 5.0 to 5.3 in forty-eight hours. Viable organisms were always present at the end of this period.

Varying amounts of culture of the two organisms were placed, simultaneously, in lactose broth fermentation tubes and incubated. Samples were removed at the end of twenty-four and of forty-eight hours and tested for acidity and for the presence of viable organisms.

The results obtained were consistent throughout the 105 tests made and can be briefly stated. At the end of twenty-four hours, the acidity was found to vary between pH 4.2 and 5.2. This difference appeared to depend upon the condition of the Clostridium welchii culture used for inoculation. When spores predominated in the culture the higher acidities (lower pH values) were more quickly reached than when few spores were present as in young cultures. After twenty-four hours' incubation Bact. coli was recovered in all but 7 instances. In these cases the pH was 4.2 or 4.3. However, Bact. coli was recovered from other tubes showing similar acidity. After forty-eight hours' incubation Bact. coli

[1] Department of Hygiene and Bacteriology, The University of Chicago, Chicago, Ill.

was never recovered when the pH values were 4.2 or 4.3. At pH values of 4.4 to 4.6 the organisms were usually but not always recovered. At higher pH values Bact. coli was consistently recovered. The relative amounts of the cultures of the two organisms used for inoculation had no apparent effect on the rate of acid production.

CONCLUSIONS

Spores of Clostridium welchii when present in lactose broth together with Bact. coli caused a rapid production of acid and gas. When this acidity reached a pH value of 4.2 or 4.3 in twenty-four hours, the recovery of colon bacilli was uncertain. At this acidity these organisms were never viable at the end of forty-eight hours. A possible interference is therefore indicated in routine water examination.

THE OXYGEN DEMAND OF POLLUTED WATERS

By E. J. Theriault

A REVIEW BY F. W. MOHLMAN[1]

It is a pleasure to acknowledge outstanding achievement in scientific research, especially when such work has been as consistent and extensive as that of Theriault in the field covered by his latest publication, "The Oxygen Demand of Polluted Waters." This is a monograph of 185 pages, issued as Bulletin 173 by the United States Public Health Service. It may be purchased from the United States Government Printing Office, Washington, for 25 cents per copy.

Some 10 or 12 years ago Theriault explained the reasons for the major difficulties in the technique of the biochemical oxygen demand test. The use of properly prepared dilution water was shown to be essential. Since then he has issued several more short papers on the same subject. The bulletin under discussion contains in Part I a critical review of the development and significance of the B. O. D. test, and in Part II the experimental results obtained by the author in his work at the Cincinnati laboratory.

The historical review in Part I includes many references to the early work of English and German investigators, extending back to experiments by Frankland in 1870. The reports of the British Royal Commission on Sewage Disposal (1891 to 1913) contain numerous articles on the development and value of the determination. The concept of a logarithmic or first-order reaction was introduced in American studies by Phelps. He did not appreciate the magnitude of the secondary stage of oxygen demand which had been noted by Adeney, and which Theriault re-stated in more precise terms in 1925. This secondary stage has been shown to be caused primarily by the oxygen requirements of nitrifying organisms.

The evidence is almost unanimous that the first stage of biochemical oxidation is concerned with the oxidation of carbonaceous organic

[1]Chief Chemist, The Sanitary District of Chicago, Chicago, Ill.

matter. This stage requires approximately 12 days at 20°C., a longer time at lower temperatures and a shorter time at higher temperatures. Theriault has experimentally tested the deoxygenation constant, K, at various temperatures, and gives an equation and tables for rates of demand over a wide range of temperature.

The standard test should be made for 5 days at 20°C., from which the demand for the first stage can be calculated. Per capita demands (first stage) are given for American sewages. It is gratifying to the reviewer to note that the factor that has been used for many years by the Sanitary District of Chicago (0.24 pounds per capita per day) is closely confirmed by data from Washington, Cincinnati, Peoria, Baltimore and Columbus. This factor applies to combined sewage relatively free from industrial wastes. For strictly domestic sewage, collected during periods of dry weather flow, the factor is approximately 0.18 pound per capita per day.

Part II contains the results of twelve series of oxygen demands for periods of incubation as long as 300 days. The data are treated mathematically to demonstrate the value of K, the deoxygenation constant, and L, the asymptotic limit of the first stage, at various temperatures. Critical studies of the precision obtainable with Theriault's technique indicate that the rate of oxygen absorption is independent of the amount of dissolved oxygen present, also that results will check in various dilutions with a standard deviation of from 5.0 to 7.5 per cent.

Although the technical details of B. O. D. work may not be of particular interest to waterworks men, the broad principles of the biochemistry of stream pollution and self-purification should interest those who are concerned with the operation of filter plants in which polluted waters are treated. Bacterial results alone do not show the state of oxidation of the organic matter present in such waters. This organic matter must go through a course of biochemical oxidation identical with that expressed by Theriault's curves. Stability will not be obtained until the carbonaceous solids are oxidized. Most raw surface waters used for potable supplies are probably beyond the carbon-oxidation stage, but many are undoubtedly in the stage of nitrification. Further study may indicate that the B. O. D. test adds something to our knowledge of filter plant loadings, in addition to bacteriological and turbidity data.

COMPARATIVE COLON-AEROGENES INDICES OF WATER AND SEWAGE[1]

By Ralph E. Noble[2]

SUMMARY

1. The colon-aerogenes content of 1051 samples of water, varying widely in sanitary quality, was determined by the cyanide-citrate agar pour plate method in parallel with the lactose broth procedure of the 1925 Standard Methods of the American Public Health Association.

2. Eight hundred and six, or approximately 76.7 per cent, of the samples examined by the plate method gave indices which equaled or exceeded those obtained by the Standard Fermentation Method. Two hundred and thirty-five samples, or 22.2 per cent, were negative for the colon-aerogenes group by both methods. One hundred and forty-one samples, or 13.4 per cent, were negative by the tube method, but positive by the plate method. Ninety-eight samples, or 9.3 per cent, were negative by the plate method, but positive by the tube method.

3. Considering the data in the aggregate, the following facts are apparent:

a. The mean plate indices exceeded the Phelps indices and the most probable number over the range of 0 to 100 colon-aerogenes organisms per 100 cc.

b. The median plate indices equaled or exceeded the Phelps indices over the range of 0 to 100 per 100 cc., but regressed from the most probable number after the Phelps index of 2 to 10,000 per 100 cc. excepting for the index of 10.

c. An expression of modal plate indices is believed to be an unfair method of presentation in this study, owing to a relatively insufficient number of items in six groups.

d. All of the plate indices were derived from 10 cc. portions except

[1] Presented before the Illinois Section meeting, March 30, 1928.

[2] Bureau of Laboratories and Research, Department of Health, Chicago, Illinois.

ten based on 1.0 cc. portions. The latter were evenly divided between the groups 1,000 and 10,000 per 100 cc.

e. In the aggregate, plate indices exceeded the Phelps indices derived from 10.0 cc. and 1.0 cc. portions. It is believed, therefore, that the smaller indices by the plate method in the groups 1,000 and 10,000 per 100 cc. can be explained as an effect of dilution.

f. Over a series of dilutions, the most representative plate index is derived from the first or second dilution lower than the Phelps, and equals or exceeds the latter. When the two types of indices are derived from dilutions wider apart than two, the Phelps index will probably exceed that by the plates. Under these conditions, however, the latter index is considered more reliable since it is founded on a relatively greater number of colon-aerogenes organisms than in the case of the one or possibly two organisms responsible for the former. This is confirmed by unpublished experimental evidence.

4. The theory of most probable numbers, while unchallengable, fails, as does the Phelps unit of measure, to take into consideration the biological principles of synergism and antibiosis often functioning in presumptive tests. This fact widens considerably the inherent degree of approximation essentially surrounding these indices because of their theoretical mathematical exactness.

5. Both the Phelps index and the most probable number are influenced by conditions common to both; hence, a change in one almost automatically means an associated change in the other, with a more or less constant mathematical difference at given magnitudes.

6. The effect of random sampling is a constant factor in both methods. From the evidence, therefore, it seems fair to conclude that the plate method is a sharper or more sensitive measure, and, hence affords a closer mathematical approximation of the actual mean density of organisms of the colon-aerogenes group in water or sewage than does the lactose fermentation method.

EXPERIMENTAL RESULTS

In a study (1) of the practicability and efficiency of the cyanide-citrate medium for the direct determination of the colon-aerogenes numbers in water and sewage, 1051 samples were examined in parallel with the Standard (2) lactose broth procedure. These samples represented water of considerable variation in sanitary quality. Collections were made of raw water from Lake Michigan, wells,

springs, swimming pools, polluted river water and sewage. The greater number examined were raw lake water.

The data to be treated do not include those of sewage owing to the difference in magnitude of dilutions and relatively small number of observations. A study of the data available on sewage, however, shows comparable results. These will be found in table 5 and figure 3, referring to the results from polluted Chicago river water, which

TABLE 1

Comparative tube and plate indices showing distribution of 1051 samples

M. P. N.*	TUBE INDEX PER 100 CC.	NUMBER OF ITEMS	PLATE INDICES								
			Number less than tube index	Per cent	Number equals tube index	Per cent	Number exceeds tube index	Per cent	Number equals or exceeds tube index	Per cent	M. P. N.†
0	0	376	0		235	62.5	141	37.5	376	100.0	0.00
2	2	210	58	27.6	39	18.6	113	53.8	152	72.4	2.00
5	4	118	43	36.4	18	15.2	57	48.4	75	63.6	4.98
9	6	85	32	37.7	13	15.3	40	47.0	53	62.3	8.92
15	8	53	16	30.2	3	5.6	34	64.2	37	69.8	14.40
38	10	50	9	18.0	3	6.0	38	76.0	41	82.0	34.70
240	100	100	43	43.0	1	1.0	56	56.0	57	57.0	228.30
2,400	1,000	44	32	72.7	0		12	27.3	12	27.3	2400.00
30,000	10,000	15	12	80.0	0		3	20.0	3	20.0	30,000.00
	Total	1,051	245	23.3	312	29.7	494	47.0	806	76.7	
Minus Equivalent Zeros		235	0		235						
Indices 2–10,000 inc.		816	245	30.0	77	9.4	494	60.6	571	70.0	

* Most probable number.

† Mean of actual most probable numbers.

may be properly termed sewage, and are illustrative also of our later sewage results.

The present standard method of expressing the number of colon-aerogenes organisms is that of Phelps in terms of 100 cc. volumes. At the same time, there is a growing tendency on the part of sanitarians to express results, either in conjunction with the Phelps index or independently, by the most probable number as developed by McCrady (3) and later amplified by Stein (4), Wolman and

Weaver (5), Yule and Greenwood (6) and Reed (7). Since these two types of indices are in current use, the cyanide-citrate agar plate indices in this study are compared with them to bring out their relative value.

It is of interest, first, to note comparisons on the basis of numbers of samples. Table 1 shows the Phelps index per 100 cc., and the corresponding most probable number, both vertically, with the number of samples having that index. These, in turn, are distributed horizontally according to those which have plate indices, (*a*) less than, (*b*) equal to and (*c*) exceeding the Phelps index. Taken in the aggregate, 245 of the samples, or 23.3 per cent, gave plate indices less than those by the lactose broth tube method. Three hundred and twelve of the samples, or 29.7 per cent, gave plate indices equal to those by the tube method, while 494, or 47.0 per cent, gave plate indices exceeding those by the tube method. Of the 245 samples, there is a fairly even distribution over the entire range with two distinct downward trends; namely, from 2 to 10 per 100 cc. and from 100 to 10,000 per 100 cc. A single downward trend of frequencies is noted in the 313 samples of equivalent indices as the Phelps index and most probable number increases. A similar trend is noted for the 493 samples having plate indices which exceed the Phelps index and most probable number. The sum of the 312 and 494 samples gives 806 samples, or 76.7 per cent, which have plate indices equal to or exceeding the tube indices. If 235 samples, which were negative by both methods, are deducted from the total 1051, there remain 816 samples having the following distribution:

NUMBER OF SAMPLES	PER CENT	COMPARISON WITH PHELPS INDEX
245	30.0	Less
77	9.4	Same
494	60.6	Greater
571	70.0	Same or greater

In table 2, there is a further comparison of the two types of indices on a sample basis. From this table it is seen that 376 of the total samples, or 35,8 per cent, were negative by the tube method, while 333, or 31.7 per cent, were negative by the plate method. Of the 376 samples negative by tube, 141 (13.4 per cent of 1051) were positive by plate. Conversely, of the 333 samples negative by plate, 98

TABLE 2

Summary of samples negative for coli-aerogenes by standard method and plate method

	NUMBER	PER CENT
Samples examined by both methods	1051	
Negative by standard method	376	35.8
Positive by plate method	141	13.4
Negative by plate method	333	31.7
Positive by standard method	98	9.3
Negative by both methods	235	22.2

TABLE 3

Summary—Mean plate indices grouped according to corresponding tube index and tabulated in the order of magnitude

GROUP	TUBE INDEX								
	0	2	4	6	8	10	100	1,000	10,000
1	0	0	0	0	0.5	2.0	10.3	36.0	128.0
2	0	0	0	0.7	2.0	4.7	28.6	70.0	170.0
3	0	0	0	2.0	4.0	8.0	42.7	113.0	180.0
4	0	0	1.5	2.7	4.0	10.7	50.9	164.0	228.0
5	0	1.7	2.0	4.0	6.5	14.7	63.7	195.0	508.0
6	0	2.0	3.0	4.6	9.3	19.5	86.7	245.0	558.0
7	0	2.1	4.0	6.0	10.0	23.3	101.0	268.0	1,036.0
8	0	4.0	4.5	6.0	12.0	32.0	120.0	360.0	2,300.0
9	0	4.3	6.5	8.0	15.0	44.5	146.0	495.0	3,040.0
10	1.3	6.0	8.9	11.0	16.7	50.7	200.0	635.0	3,700.0
11	2.0	7.1	10.0	17.7	21.0	56.7	316.0	820.0	5,300.0
12	3.0	9.4	12.0	23.6	28.7	76.0	482.0	1,190.0	9,300.0
13	5.2	13.6	16.0	36.8	44.0	105.3	839.0	1,580.0	16,400.0
14	9.8	22.4	22.2	93.0	73.3	151.3	1,470.0	2,180.0	29,400.0
15	53.0	121.0	244.0	922.0	478.0	559.0	3,200.0	5,450.0	32,600.0
*	4.9	12.9	22.6	69.0	51.9	83.6	462.0	933.0	6,990.0
†	0.0	4.0	4.0	6.0	12.0	35.0‡	117.0‡	360.0‡	2,300.0

* Mean of total respective plate items for corresponding Phelps index.
† Median plate items for corresponding Phelps index.
‡ Interpolated medians.

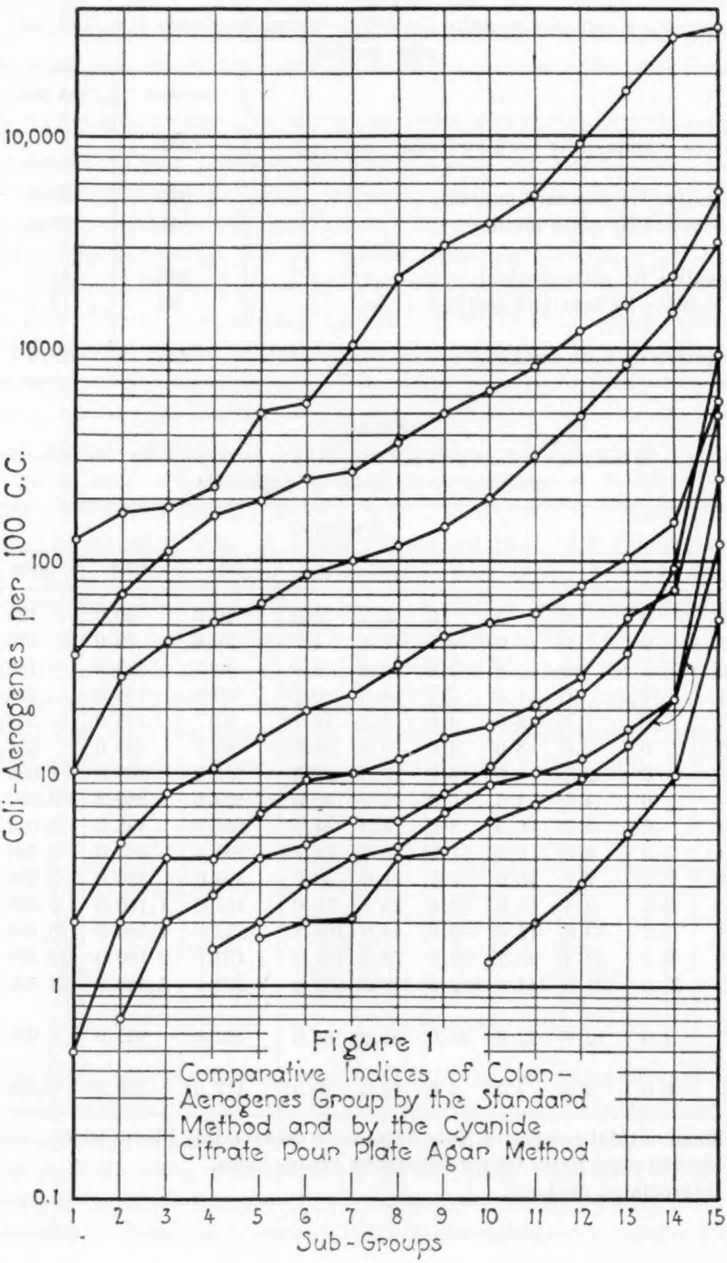


Figure 1
Comparative Indices of Colon-Aerogenes Group by the Standard Method and by the Cyanide Citrate Pour Plate Agar Method

(9.3 per cent of 1051) were positive by tube. The difference of 235 samples (22.2 per cent of 1051) were negative by both methods.

COMPARATIVE INDICES AT SPECIFIC MAGNITUDES

In order to study the relationship between the indices of Phelps, the corresponding most probable number, and the indices by the plate method, all of the latter were grouped according to the corresponding tube index, e.g. each of 118 samples gave a Phelps index of 4 per 100 cc., while the corresponding plate indices varied in magnitude from 0 to 1102 per 100 cc. Again, each of 15 samples gave a

TABLE 4

Comparative indices of the colon-aerogenes group by Phelps, most probable number and plate methods

Index per 100 cc.

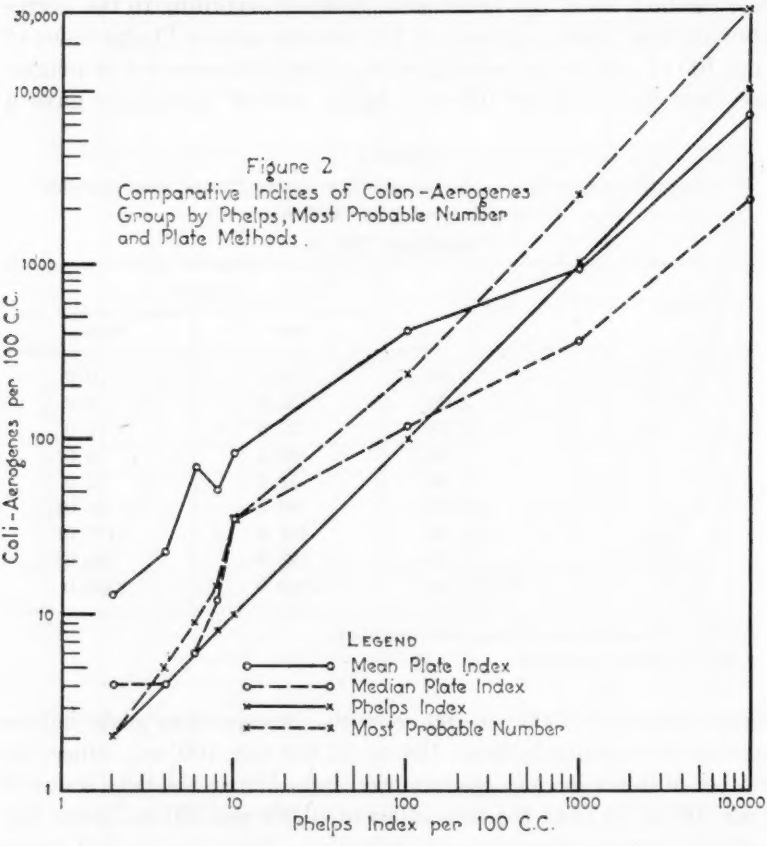
PHELPS	M. P. N.*	PLATE	
		Mean	Median
0	0.00	4.9	0.0
2	2.00	12.9	4.0
4	4.98	22.6	4.0
6	8.92	69.0	6.0
8	14.40	51.9	12.0
10	34.70	83.6	35.0†
100	228.30	417.0	117.0†
1,000	2,400.00	933.0	360.0†
10,000	30,000.00	6990.0	2300.0

* Mean of actual most probable numbers.
† Interpolated medians.

Phelps index of 10,000 per 100 cc. with corresponding plate indices varying in magnitude from 128 to 32,600 per 100 cc. Since the number of items in each group varied from 376 at the tube index of 0 per 100 cc. to 15 at the tube index of 10,000 per 100 cc., some fair method of group comparison was essential. Since the smallest group contained 15 items, above mentioned, all items in this and each of the other groups were tabulated in the order of magnitude and divided into 15 sub-groups. Each sub-group was composed of an equal number of items, or a number derived by an equitable distribution of items in cases of totals not evenly devisible by 15. This procedure placed each group representing specific tube indices from 0 to 10,000

per 100 cc., on a common basis and facilitated tabular and graphic comparison. Table 3 summarizes the data as described.

Figure 1 presents the data graphically on semi-log paper with the mean plate count colon-aerogenes indices per 100 cc. plotted as ordinates and sub-groups indicated as abcissae. There are nine plots corresponding to the nine Phelps indices from 0 to 10,000 per



100 cc. The fact brought out by table 3 and figure 1 is the relative magnitude and frequency of plate indices in relation to the Phelps index of each major group, viz., 0 per 100 cc., 2 per 100 cc., 4 per 100 cc., etc.

Another comparison is made in table 4 and figure 2, in which is also indicated the corresponding computed mean most probable number

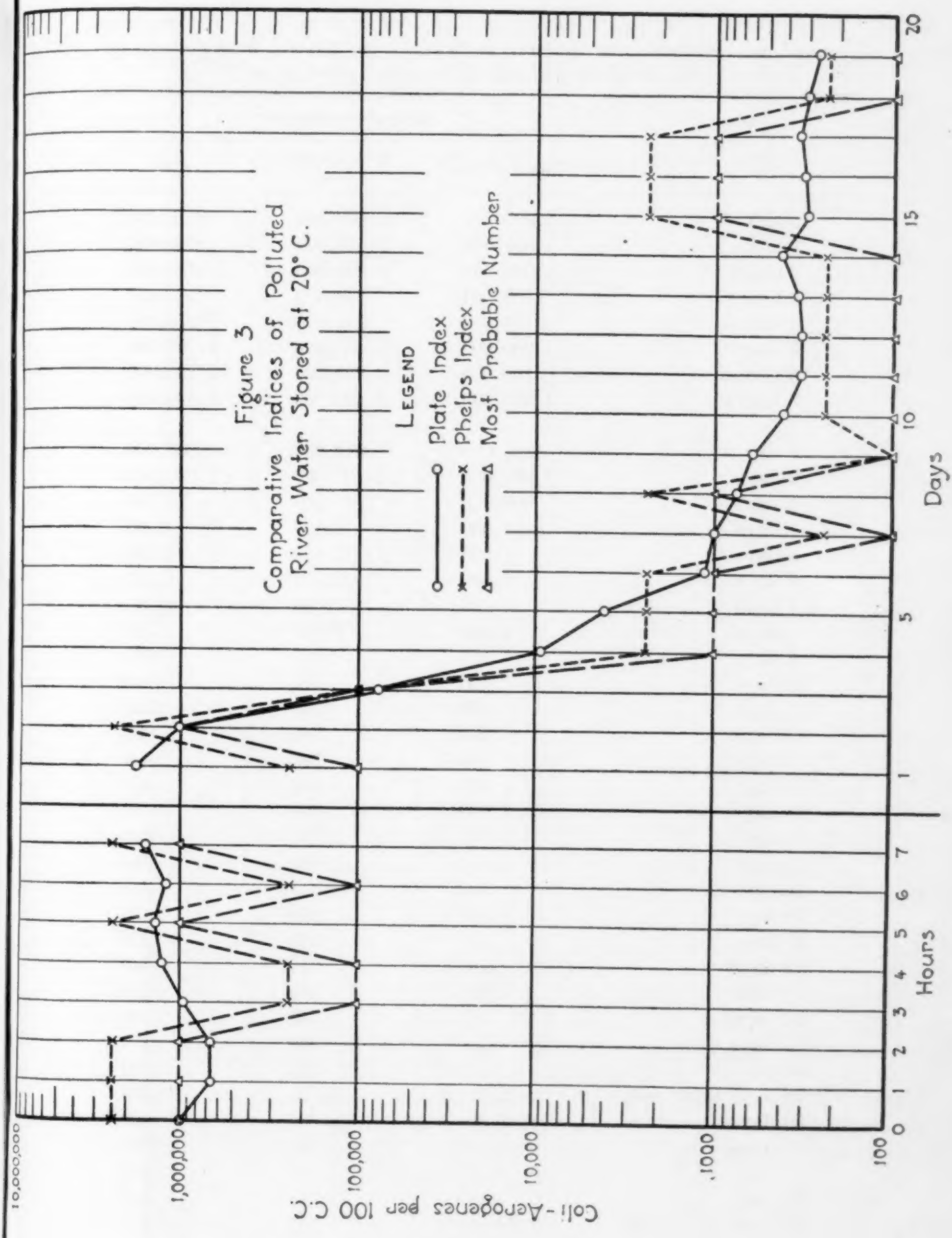


Figure 3
Comparative Indices of Polluted River Water Stored at 20° C.
Legend
Plate Index
Phelps Index
Most Probable Number
Coli-Aerogenes per 100 C.C.
10,000,000
1,000,000
100,000
10,000
1000
100
Hours
0
1
2
3
4
5
6
7
Days
1
5
10
15
20

TABLE 5

Comparative numbers of coli-aerogenes expressed in terms of the Phelps (tube) index, most probable numbers and plate index per 100 cc., progressively for 16 to 18 liters polluted river water stored at 20°C.

TIME	MEAN INDEX PER 100 CC.		
	Phelps (Tube)	Most probable number	Plate
Initial	1,000,000	2,400,000	995,000
1 hour	1,000,000	2,400,000	660,000
2 hours	1,000,000	2,400,000	670,000
3 hours	100,000	240,000	950,000
4 hours	100,000	240,000	1,275,000
5 hours	1,000,000	2,400,000	1,400,000
6 hours	100,000	240,000	1,230,000
7 hours	1,000,000	2,400,000	1,580,000
1 day	100,000	240,000	1,800,000
2 days	1,000,000	2,400,000	1,030,000
3 days	100,000	95,500	76,500
4 days	1,000	2,400	9,400
5 days	1,000	2,400	4,200
6 days	1,000	2,400	1,130
7 days	100	240	1,010
8 days	1,000	2,400	750
9 days	100	95	620
10 days	100	240	420
11 days	100	240	330
12 days	100	240	330
13 days	100	240	350
14 days	100	240	430
15 days	1,000	2,400	310
16 days	1,000	2,400	320
17 days	1,000	2,400	340
18 days	100	240	310
19 days	100	240	270
21 days	100	240	220
22 days	100	240	340
23 days	1,000	955	310
24 days	100	240	230
25 days	100	240	170
26 days	100	240	190
29 days (agitated)	10,000	24,000	20,600
30 days	1,000	2,400	920
31 days	100	240	780
32 days	1,000	2,400	610
36 days	100	240	390
36 days (agitated)	10,000	24,000	2,390
37 days	1,000	2,400	460

for each major group. These means are computed from the same data as were the individual Phelps indices and so take into consideration the "anomalous" results or "skips" (failure of some lower dilution tube to be confirmed). The *theoretical* most probable number for each Phelps index in table 4 would not take these actual "skips" into consideration; hence, they would be unsuitable for comparison in this study. For comparison with the arithmetic mean of each major group there are shown the corresponding median items. Interpolated medians are so indicated.

To bring out the comparison of the Phelps index and the most probable number with the plate index, a 16 to 18 liter sample of polluted river water was stored at 20°C. over a period of 37 days. Table 5 shows the data while figure 3 shows the several progressive indices, the marked smoothness and relative magnitude of the plate index curve.

DISCUSSION

It may be well to refer briefly to the conception of the Phelps index and McCrady's most probable number. The former method assumes the presence of at least *one* colon-aerogenes organism in the highest dilution of a sample developing gas when multiple dilutions are planted in standard lactose broth. The resulting index is then to be interpreted as an approximation of the actual number of colon-aerogenes organisms present in the sample tested. It is generally appreciated, of course, that a plural number may be present in such a dilution yet not to the extent to be consistently reflected in the next higher dilution, or if only one colon-aerogenes organism is accountable for a positive highest dilution, that organism may represent a chance "pick-up," the greater frequency of numbers existing nearer to the next lower dilution, or that any degree of these two conditions may exist between the two extremes indicated. McCrady endeavored to solve this difficulty with his theory of most probable numbers. The theory explains and measures by formula "The probabilities of occurrence of densities of B. coli from the results of any of the usual sampling procedures with given combinations of dilutions. . . . ." When "anomalous" results or "skips" occur, they are taken into consideration and alter the most probable number to the extent of their "abnormality." The theory is mathematically correct and unchallengable. With the geometrically increasing magnitude of numbers there is a consistently increasing numerical difference

between the Phelps index and the most probable number. After the index 100 per 100 cc. this difference has the character of a constant which likewise increases geometrically. Thus, aside from the "anomalous" cases, a change in the Phelps index means a corresponding change in the most probable number, yet the relation is always constant for a specific Phelps index. Thus, because the most probable number is derived from the same analytical data as the Phelps index, the former index as well as the latter must be regarded as an approximation.

Aside from the mathematical considerations in connection with tube indices and most probable number, and the resulting necessity of interpreting such indices as approximations, the value of these data is further interfered with by the phenomena of synergism (8) and antibiosis (9). These phenomena very often operate in the presumptive tube. Usually their net effect is to reduce the number of colon-aerogenes organisms originally present.

If a successful plate method of indexing avoids the vitiating effect of synergism and antibiosis, as well as some of the mathematical difficulties associated with the tube method, the fact should be reflected in comparative tests. On referring to figure 2, it is seen for the range 0 to 10 per 100 cc., the mean plate index in a pronounced way exceeds the median plate index, Phelps index and most probable number. Since these comparatively high means doubtless are influenced by the relatively high counts in the array of items, the median item of each group has been plotted. Likewise, it is seen the median exceeds the Phelps index at all points in the range 0 to 100 per 100 cc., excepting at 6 per 100 cc. and 8 per 100 cc., where the two types of indices are equivalent. With a greater number of items than 85 for this group, it is believed the median plate count would exceed 6 per 100. Except at 2 per 100 cc. and 10 per 100 cc., the most probable number exceeds the median plate count in the range 0 to 100 per 100 cc.

Statistical analysis of the data does not indicate that a determination of the mode, or item of greatest frequency, in each group, would be a fair criterion of that group. A definite mode is indicated only in the first three groups. Its failure to be so indicated in the remaining groups is attributed to an insufficient number of items.

In the range 1,000 to 10,000 per 100 cc., we find a different picture. Here both the tube index and most probable number progressively exceed the average and median plate indices.

It might appear, therefore, that the plate method is more efficient in the range 0 to 100 per 100 cc. than from 1,000 to 10,000 per 100 cc. This is not believed true, however, when it is considered that *all* plate indices *except* 10 were obtained from 10.0 cc. portions. Ten indices were obtained from 1.0 cc. portions, five falling under the Phelps index group of 1,000 per 100 cc. and five in the group 10,000 per 100 cc. In the light of this fact, the difference in magnitude between indices in the last two groups, as already pointed out, probably is explained by and serves to illustrate one of the conditions mentioned in the foregoing, namely, that the highest dilution shown positive for Bact. coli may be accounted for by a single organism, as a result of dilution, while the greater frequency of numbers may exist nearer to the next or the second lower dilution. If this is true, as it seems, then the plate index is the more accurate one, being based on the next or second lower dilution than that of the highest positive tube index. Evidently the latter represents a zone of comparatively few absolute numbers while the former represents a zone of comparatively greater absolute numbers. In the zone of few absolute numbers, measured with like volumes (10.0 cc.) by both methods, the plate method seems to be quite the more accurate, over and above the effect of random sampling. Consequently, if plate indices in the range 1,000 to 10,000 per 100 cc. were based on the same volumes as were the tube indices, a similar relationship should obtain. Experimental work bearing upon this angle is in progress.

ACKNOWLEDGMENT

Appreciation is expressed to Dr. Fred O. Tonney, Director of Laboratories and Research, and Frank E. Greer, both of the Chicago Department of Health, and to Dr. I. S. Falk, Department of Bacteriology, University of Chicago, for their constructive criticism and aid in preparing this article.

DISCUSSION

LOWELL J. REED:[3] I was very much interested in seeing Mr. Noble's paper in advance of its publication. From the point of view of the conclusions drawn, the fact of most interest in the statistical treatment is the smoothness of the results obtained from the plate

[3] Head of Department of Biometry and Vital Statistics, The Johns Hopkins University, Baltimore, Md.

counts of stored water, in contrast to either the Phelps' Index or that of the most probable number, and it seems that this fact constitutes the strongest argument for a plate method. On general statistical grounds, it would be expected that a counting process would be superior to that process involving fermentation tubes; for both the Phelps' Index and the most probable number depend upon a type of inverse probability analysis that makes them much more uncertain than would be any probability or proportion determined through a direct, counting process.

A final decision as to which procedure is the superior must take into account, however, many other factors than the relative statistical errors of the methods involved.

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INFLUENCE OF PHOSPHORUS ON STRENGTH PROPERTIES OF CAST IRON PIPE

By James T. MacKenzie[1]

In a previous publication, "The Influence of Phosphorus on Cast Iron," (Transactions of the American Foundrymen's Association, vol. 34, p. 986, 1926), it was shown that the influence of phosphorus

TABLE 1

Samples of pipe

LOT NUMBER	MANUFACTURER	PURCHASED FROM
	Tested by Prof. A. N. Talbot	
1	American Cast Iron Pipe Company	Manufacturer
2	American Cast Iron Pipe Company	Manufacturer
4	American Cast Iron Pipe Company	Manufacturer
40	Jas. B. Clow & Sons	Manufacturer
70	National Cast Iron Pipe Company	Dealer
71	Jas. B. Clow & Sons	Chicago
72	U. S. Cast Iron Pipe & Foundry Company (Addyston)	Chicago
73	U. S. Cast Iron Pipe and Foundry Company (Bessemer)	Detroit
	Tested by Jas. T. MacKenzie	
HP	American Cast Iron Pipe Company	Manufacturer
B	Stamped Cie Gie Liege 1926, Made in Belgium	Dealer
F	Stamped P.M.-A.V. 1926, Made in France	Dealer

per se was to weaken and stiffen cast iron. However, it was shown by citation of Professor Talbot's work on 6-inch cast iron pipe (Journal of American Water Works Association, June, 1926) that amounts up to approximately 0.80 per cent might, by increasing the fluidity of the molten metal, give a sounder, and hence better pipe than lower percentages, for example 0.50 per cent. Since writing this

[1] Metallurgist, American Cast Iron Pipe Company, Birmingham, Alabama.

paper two lots of pipe have been obtained containing high phosphorus, and one lot was cast at Acipco with an intermediate content of 1.25 per cent phosphorus, which are of interest, in that they prove that the intrinsic weakness of the high phosphorus iron is decidedly manifest when the 1 per cent point is passed, in spite of the increased fluidity of such metal.

The vertical sand cast pipe tested by Professor Talbot in his revised drop test, except as noted below, have been used as a base. These are shown in table 1.

Lots 4 and 71 were not tested in the revised drop test, but as they both were of peculiar importance to the treatment of the subject, they were included and the drop test calculated from the average ratio of the new to the old test on the other sets, which show as follows:

LOT	6-INCH DROP	3-INCH DROP	RATIO
1	16.7	8.5	0.51
2	15.3	8.1	0.53
3	17.7	9.5	0.54
40	20.3	10.1	0.50
70	14.4	8.1	0.56
72	14.4	11.4	0.62
73	14.2	8.6	0.61
Average			0.55

It is very probable that the true values would not be far from those calculated, as the ratios show fairly close agreement for the several lots.

The reason for the inclusion of lot 4 was that this iron is probably the only one that compares with lot HP in the temperature of melting. As will be apparent from figure 1, lot HP shows up very well indeed as compared with Talbot's group I, but if we compare it directly with lot 4, we see the true tendency of the phosphorus.

Lot 71 was included primarily to show another low phosphorus lot. Its carbon content is too high to permit averaging it with lot 40, and its superior performance in the bursting test shows that it was more fluid and produced a sounder casting on account of the high carbon, the silicon remaining nearly the same. Its lower value in drop test and in resilience may be due partly to the higher carbon,

but probably are due largely to the accidents of selection as this was a job lot purchased from the City of Chicago.

Lot 2 was included because it was the only lot in Talbot's test with silicons to compare with the foreign pipe. Though listed by Talbot under group V, it was made exactly as group I, the only difference being the change of mixture to get a soft iron.

The tests carried out by the writer were made exactly as described by Talbot, using the same apparatus and technique. Values for the bursting test are shown in table 2.

No flexure tests were made on the full length of pipe as it was shown (Proceedings of A. S. T. M., vol. 26, part II, p. 214, 1926)

TABLE 2

Bursting tests

LOT	PRESSURE	THICKNESS	TENSILE STRENGTH	AVERAGE
		inch	*pounds per square inch*	*pounds per square inch*
HP	1,650	0.41	12,500	14,000
	2,250	0.44	15,800	
	2,100	0.47	13,600	
B	1,400	0.39	10,800	11,400
	1,000	0.30	10,000	
	2,000	0.45	13,300	
	650	0.32	6,100*	
F	1,800	0.40	13,500	12,400
	1,380	0.34	12,100	
	1,800	0.46	11,700	

* Hot cracks—not averaged.

that the agreement between the strip test and the full flexure test was very good indeed. As a machine for the full flexure test was not available this test was omitted.

The drop tests were made 2 feet from bell and spigot ends, and in the middle of the pipe, the supports being 2 feet apart, the hammer 50 pounds, the first fall 6 inches and the increments 3 inches to failure. The "height of drop" is that of the last blow, which caused failure. The "drop test" value used here in the discussion is the "height of drop" divided by the three halves power of the thickness at the break, this being the relation obtained by Talbot, and gives

TABLE 3

LOT	POSITION	HEIGHT DROP	THICKNESS TOP	t^2	DROP TEST	AVERAGE	GENERAL AVERAGE
			inches				
		3.00	0.50	0.353	8.5		
	Bead	3.00	0.48	0.332	9.0	8.5	
		2.75	0.49	0.343	8.0		
		3.25	0.53	0.386	8.4		
1	Middle	3.00	0.50	0.353	8.5	7.9	8.5
		2.50	0.52	0.375	6.7		
		3.50	0.54	0.397	8.8		
	Bell	3.25	0.51	0.364	8.9	9.2	
		3.00	0.45	0.302	9.9		
		2.75	0.53	0.386	7.1		
	Bead	2.50	0.49	0.343	7.3	7.6	
		2.75	0.47	0.322	8.5		
		3.00	0.50	0.353	8.5		
2	Middle	3.50	0.52	0.375	9.3	8.3	8.1
		1.75	0.39	0.244	7.2		
		2.50	0.47	0.322	7.8		
	Bell	3.50	0.53	0.386	9.1	8.6	
		2.50	0.43	0.282	8.9		
	Bead	3.25	0.51	0.364	8.9	8.7	
		3.00	0.50	0.353	8.5		
40	Middle	4.00	0.52	0.375	10.7	9.6	10.1
		3.00	0.50	0.353	8.5		
	Bell	4.75	0.54	0.397	11.9	12.1	
		4.75	0.53	0.386	12.3		
	Bead	2.50	0.52	0.375	6.7		
70	Middle	2.75	0.50	0.353	7.8	8.1	
	Bell	3.50	0.50	0.353	9.9		
	Bead	3.00	0.50	0.353	8.5		
72	Middle	3.75	0.45	0.302	12.4	11.4	
	Bell	4.75	0.50	0.353	13.4		
	Bead	3.50	0.53	0.386	9.1		
73	Middle	3.75	0.58	0.442	8.5	8.6	
	Bell	3.00	0.51	0.364	8.2		

TABLE 3—*Continued*

LOT	POSITION	HEIGHT DROP	THICKNESS TOP	$t^{\frac{3}{2}}$	DROP TEST	AVERAGE	GENERAL AVERAGE
			inches				
HP	Bead	2.25	0.46	0.312	7.2	6.9	7.3
		2.50	0.47	0.322	7.8		
		1.75	0.45	0.302	5.8		
	Middle	2.50	0.49	0.343	7.3	7.0	
		2.25	0.49	0.343	6.6		
		2.25	0.46	0.312	7.2		
	Bell	2.75	0.48	0.332	8.2	7.9	
		2.75	0.47	0.322	8.5		
		2.00	0.43	0.282	7.1		
B	Bead	2.75	0.47	0.322	8.5	8.0	6.5
		2.50	0.44	0.292	8.6		
		2.25	0.48	0.332	6.8		
	Middle	1.75	0.44	0.292	6.0	6.2	
		2.00	0.44	0.292	6.8		
		2.00	0.50	0.353	5.7		
	Bell	1.75	0.48	0.332	5.3	5.5	
		1.50	0.36	0.216	6.9		
		1.50	0.50	0.353	4.3		
F	Bead	2.00	0.48	0.332	6 0	6.4	5.1
		2.00	0.50	0.353	5.7		
		2.25	0.45	0.302	7.45		
	Middle	1.25	0.45	0.302	4.1	4.4	
		1.50	0.42	0.272	5.5		
		1.50	0.56	0.419	3.6		
	Bell	1.50	0.47	0.322	4.7	4.63	
		1.50	0.50	0.353	4.25		
		1.75	0.50	0.353	4.95		

the hypothetical drop necessary to break a pipe of the same material exactly 1 inch thick. As the detailed results of the Talbot tests were never published they are given here in table 3. All calculations were made by myself, using the thickness at the break instead of the average thickness used by Talbot in his graph.

The strip tests were taken from approximately the same position

TABLE 4

Strip test on lots HP, F and B

LOT	BEAD		MIDDLE		BELL	
	Modulus rupture	Modulus elasticity	Modulus rupture	Modulus elasticity	Modulus rupture	Modulus elasticity
HP	43.2	7.45	42.0	7.63	37.1	8.05
	40.5	8.35	39.0	7.58	38.9	7.52
	40.0	9.00	40.0	7.93	36.7	7.82
	41.2	8.27	40.3	7.71	37.6	7.80
B	28.6	7.2	38.9	8.7	37.3	9.4
	42.2	7.8	33.3	7.3	35.6	8.0
	33.3	7.8	30.2	9.9	30.5	8.7
	34.7	7.6	34.1	8.6	34.5	8.7
F	27.8	8.5	29.5	9.0	29.4	8.9
	33.4	10.2	36.7	9.8	38.2	12.5
	33.3	8.9	34.3	9.1	35.9	9.0
	31.5	9.2	33.5	9.3	34.5	10.1

Note: Modulus of rupture stated in thousands of pounds per square inch and modulus of elasticity in millions.

TABLE 5

Tensile tests (de Lavaud bar)

LOT	BEAD	MIDDLE	BELL
HP	22,600	29,200	23,500
	21,200	23,400	
	24,600	23,400	23,100
	22,800	25,300	23,300
B	21,500	26,000	26,900
	18,900	18,300	20,400
	20,800	22,600	22,000
	20,400	22,300	23,100
F	18,300	17,600	21,400
	23,300	19,600	16,400
	20,300	20,300	21,300
	20,600	19,200	19,700

as the drop tests and were cut from the same pipe. They were broken on a Riehlé 5000 pounds Universal machine, which will "break" under a half pound, and deflections were read on a 10 to 1

deflectometer reading to the thousandth part of an inch. Both load and deflection were automatically recorded by the Marshall recorder (Proceedings of A. S. T. M., vol. xx, p. 361, 1920). The results of the strip tests are shown in table 4. The "resilience factor" was calculated by dividing the square of the modulus of rupture by the modulus of elasticity, which gives the triangular resilience, or Pd/b (where P equals load, d equals deflection and b equals width), and correcting for curvature by Talbot's figure for group I, i.e., 28 per cent. In the three groups tested by the writer resilience was determined by planimeter, and the excess of full resilience over the triangular was used, to calculate the factor comparable to that used on the other lot. This amount to 20 per cent for lot HP, 14 per cent for lot B, and only 11 per cent for lot F, as the bending curve approaches a straight line as the phosphorus increases.

TABLE 6

Brinnell Hardness Numbers—3000 kgm. and 10 mm. Ball, 30 seconds

LOT	INSIDE	OUTSIDE	AVERAGE
1	174	186	180
40	187	187	187
HP	176	196	186
B	178	184	181
F	196	216	206

The tensile bar used for comparison is that adopted by the United States Cast Iron Pipe and Foundry Company as the acceptance test for deLavaud pipe. We do not consider this test to be a good one for the type of pipe under discussion here, and for that reason Talbot used another type of specimen in addition. The advantages of using a recognized standard decided for this bar in the present tests, in spite of its objectionable feature, which is that it uses only the weakest portion of the pipe wall, i.e., the interior where the two sets of crystals meet in freezing. Ninety per cent of the flaws in a vertically sand cast pipe will occur in this section, where they are relatively harmless from the users standpoint, but loom large in making small tensile tests. Unfortunately Talbot did not use the tensile tests on lots 70 to 73. Results on the three lots tested are shown in table 5.

Brinnell hardness is not considered of particular importance, but

the average values are shown in table 6, together with two lots tested by Talbot, which were not published. It is interesting to note that Petrenko (Technologic paper, Bureau of Standards No. 336, "Comparative Tests of Six-Inch Cast Iron Pipe of American and French Manufacture") obtained an average Brinnell number of 177 for seven lots of American pipe and 216 for the French pipe, as against Talbot's 183 on two lots of group I and my 206 for lot F.

In table 7 are assembled the average values for each lot in Bursting Strength, Drop Test, Strip Test, Tensile Test and Chemical

TABLE 7

Lot number	Phosphorus	C + Si/3	Bursting strength	Drop test	Strip test		Resilience factor	De Lavaud tensile	Analysis				
					Modulus rupture	Modulus elasticity			C	Si	S	Mn	Mn/S
40	0.49	4.05	13.4	10.1	39.1	7.4	264	23.1	3.50	1.65	0.08	0.50	6
71	0.51	4.25	14.6	8.8*	32.5	6.7	202	N.D.	3.72	1.58	0.05	0.70	14
72	0.70	4.17	14.4	11.4	32.5	6.6	205	N.D.	3.64	1.58	0.06	0.46	8
4	0.77	4.03	16.1	9.1	38.3	7.2	261	21.6	3.56	1.40	0.07	0.34	5
1	0.80	4.13	13.9	8.5*	35.3	7.5	213	23.2	3.67	1.38	0.06	0.34	6
2	0.84	4.22	14.4	8.1	39.1	6.9	291	23.7	3.53	2.07	0.05	0.48	9
73	0.86	4.04	16.4	8.6	35.0	7.3	215	N.D.	3.51	1.60	0.06	0.35	6
70	0.88	4.04	14.8	8.1	35.0	7.2	218	N.D.	3.56	1.44	0.05	0.38	8
HP	1.25	4.03	14.0	7.3	39.7	8.0	237	23.8	3.46	1.71	0.09	0.46	5
B	1.54	4.16	11.4	6.5	34.4	8.3	163	21.9	3.26	2.70	0.09	0.44	5
F	1.77	4.04	12.4	5.1	33.2	9.5	129	19.8	3.35	2.07	0.06	0.40	7

* Drop test on lots 4 and 71 not determined. Calculated from Talbot's first test by the ratio of that test to the new one, viz., 6-inch increment on 10-foot supports × 0.55 = 3-inch increment on 2-foot supports.

N.D.—not determined.

Analysis. The arrangement is in order of increasing phosphorus content. Figure 1 gives a graphical exposition of the principal data: Bursting Strength, Drop, Resilience, and Tensile Tests being plotted against phosphorus, and the sum of the carbon and one-third of the silicon is shown. The figure shows clearly the pronounced weakening effect of the phosphorus in all of the tests above 1.25 per cent. Up to this point other variables seem to be of greater importance. It has already been mentioned that the lot at 1.25 per cent phos-

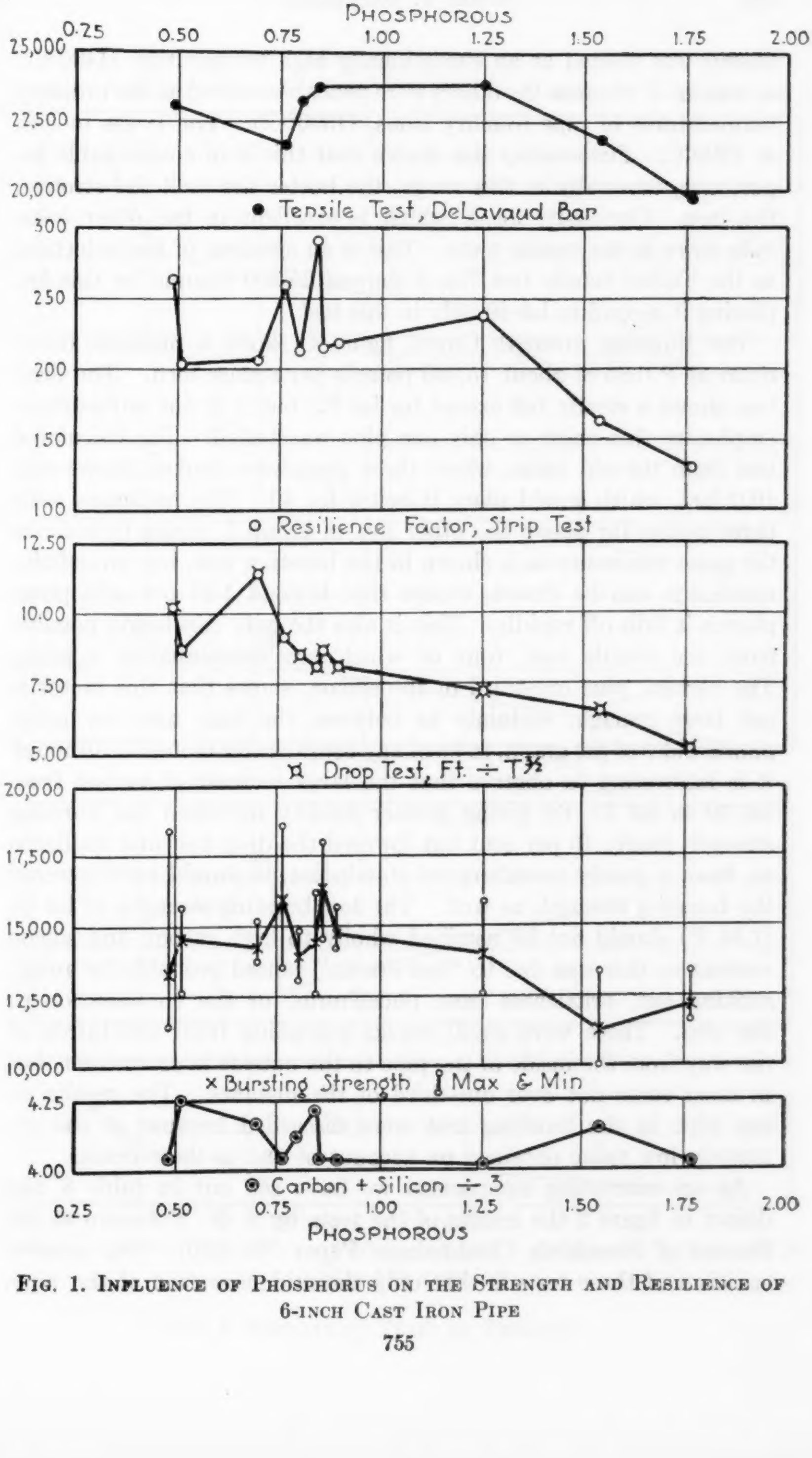

Fig. 1. Influence of Phosphorus on the Strength and Resilience of 6-inch Cast Iron Pipe

phorus was melted at an exceptionally high temperature (1400°C.) as was lot 4, whereas the others were probably melted at the ordinary temperatures of pipe foundry irons, (1300°C.). Lot 1 was melted at 1290°C. Piwowarsky has shown that this is of considerable importance, especially in this range; the hotter the melt the stronger the iron. Curiously, lot 4, which is excellent in the other tests, falls down in the tensile tests. This is an accident of test selection, as the Talbot tensile test No. 2 showed 25,400 pounds for this lot, placing it second to lot 40 only in this test.

The Bursting Strength Curve, figure 1, shows a probable maximum at P 0.80 of about 15,000 pounds per square inch. The drop test shows a steady fall except for lot 72, but it is not advisable to emphasize this point as only one pipe was tested. The calculated test from the old value, where three pipes were broken, shows only 10.0 feet, which would place it below lot 40. The resilience, with three points far above the other five of group I, seems to indicate the same maximum as is shown in the bursting test, but no definite conclusion can be drawn, except that beyond 1.25 per cent phosphorus it falls off rapidly. This is also the only conclusion possible from the tensile test, four of which are unfortunately missing. The carbon, plus one-third of the silicon, shows that this factor is not large enough, certainly as between the high and low phosphorus sides of the graph, to be of any considerable moment, although it is interesting to observe that the large increase of carbon from lot 40 to lot 71, by giving greater fluidity increased the bursting strength nearly 10 per cent but lowered the drop test and resilience as, from a purely metallurgical standpoint, it should have lowered the bursting strength as well. The low bursting strength of lot B, (1.54 P) should not be ascribed wholly to high carbon and silicon content as this was due to "hot cracks" caused probably by rough shaking out, brittleness from phosphorus, or the combination of the two. These were small cracks extending from two-thirds of the way from the inside of the pipe to the outside in some cases, but in most cases not over one-third of the distance. The results on one pipe in the bursting test were discarded because of the extremely low value obtained on account of one of these cracks.

As an interesting comparison we have set out in table 8 and drawn in figure 2 the results of the tests by S. N. Petrenko at the Bureau of Standards (Technologic Paper No. 336). Our general criticism of these tests is that only the middle section of the pipe,

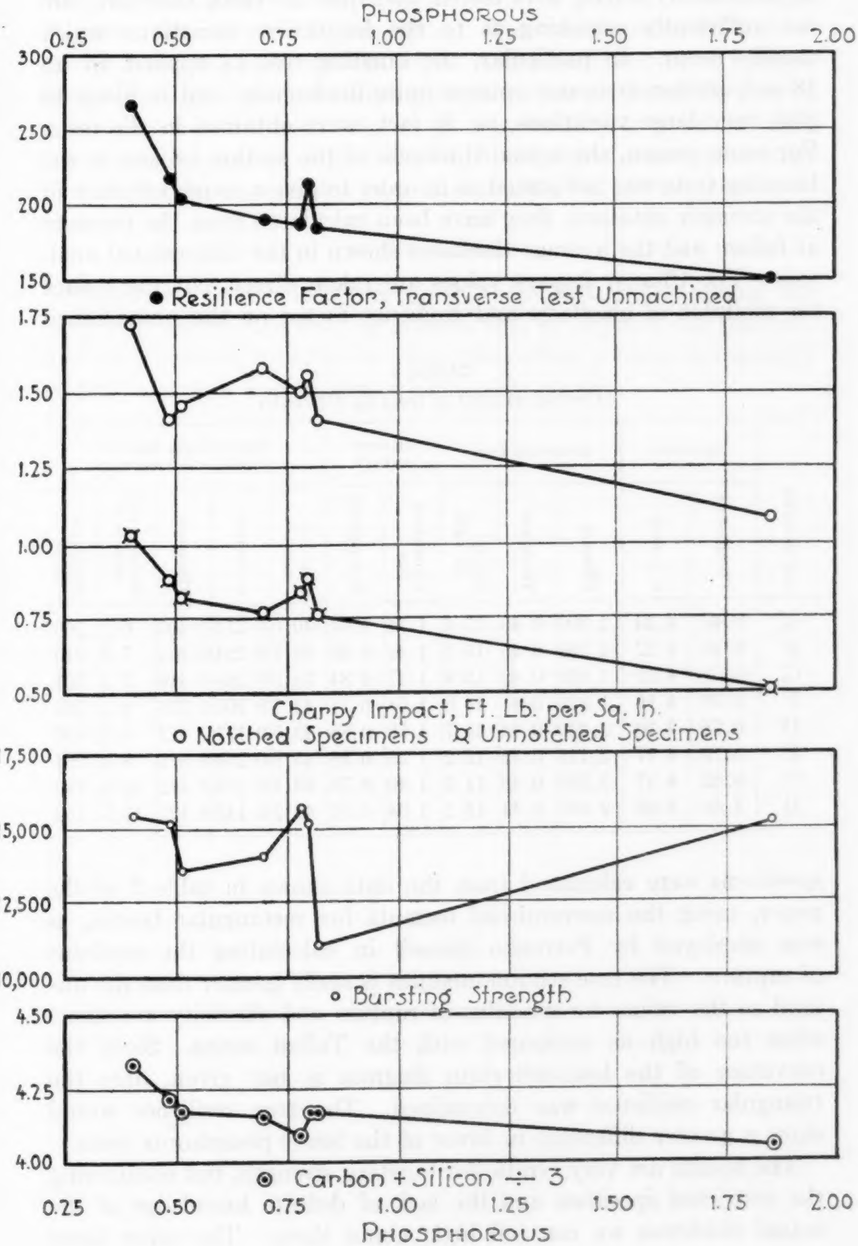

FIG. 2. RESULTS OF TESTS BY PETRENKO

approximately 5 feet, were tested, and that the tests, therefore, are not sufficiently searching as to the lengthwise variations which usually occur. In particular, the bursting test as applied to an 18-inch section is in our opinion quite inadequate, and is likely to give very large variations, as, in fact, were obtained in the tests. For some reason, the actual thickness of the section broken in the bursting tests was not stated so in order to give a rough estimate of the strength obtained, they have been calculated from the pressure at failure and the average thickness shown in the dimensional analysis. The Charpy impact values are taken direct, but the values for modulus of elasticity and resilience factor on the unmachined

TABLE 8

Partial exhibit of tests by Petrenko

Lot number	Analysis		Bursting test			Charpy impact		Transverse test on unmachined samples				
	Phosphorus	C + Si/3	Pressure	Thickness	Tensile strength	Unnotched bar	Notched bar	Modulus rupture	Deflection	Thickness	Modulus of elasticity	Resilience factor
A	0.40	4.33	2,200	0.43	15.4	1.74	1.04	40.0	0.274	0.405	6.0	266
B	0.48	4.22	2,290	0.45	15.3	1.42	0.90	39.7	0.224	0.409	7.2	219
G	0.51	4.19	1,910	0.42	13.6	1.47	0.84	38.3	0.209	0.416	7.3	201
F	0.70	4.16	1,920	0.41	14.0	1.58	0.77	42.1	0.200	0.376	9.3	191
D	0.78	4.10	2,420	0.46	15.7	1.50	0.85	42.5	0.177	0.422	9.5	190
E	0.79	4.17	2,115	0.42	15.2	1.55	0.88	45.9	0.254	0.376	8.0	264
C	0.82	4.17	1,590	0.43	11.1	1.40	0.76	43.3	0.173	0.412	10.1	186
H	1.85	4.05	2,210	0.44	15.1	1.08	0.51	42.2	0.142	0.422	11.7	152

specimens were calculated from the data shown in table 7 of the paper, using the conventional formula for rectangular beams, as was employed by Petrenko himself in calculating the modulus of rupture. The true section modulus is really greater than the one used so the values for modulus of rupture and elasticity are somewhat too high as compared with the Talbot strips. Since the curvature of the load-deflection diagram is not given, only the triangular resilience was determined. The true resilience would show a greater difference in favor of the lower phosphorus irons.

The results are very erratic for bursting strength, but considering the restricted specimen and the lack of definite knowledge of the actual thickness we can tell little about them. The other three

tests, or rather the three different ways of getting at the same property, show a striking similarity. The maximum at 0.80 phosphorus indicated in figure 1 is not so strong here, but there is more than a hint of it, and the high phosphorus shows decidedly low in the resilience and impact values. It is interesting to point out that the especially good lot with 0.40 phosphorus, lot A, has again a high C + Si/3 content and this time it shows well in all the tests.

CONCLUSIONS

Phosphorus in cast iron pipe up to about 0.80, by increasing the fluidity of the molten iron, in general acts to improve the product. Beyond 1 per cent its intrinsic embrittling effect become increasingly evident, strength and resilience decreasing rapidly.

COMMENTS ON REVISION OF MANUAL OF WATER WORKS PRACTICE[1]

MR. HOWARD A. DILL:[2] The Manual of Water Works Practice published by the American Water Works Association in 1925 is a valuable publication.

It would not be possible in one volume to cover in detail the investigations necessary to plan, install, finance and operate a water plant.

The Manual was intended to cover the field in a general way, giving fundamental principles and data incident thereto. It cannot fit all cases. It may contain irrelevant material to some, or it may be deficient for others. For instance, for a plant having an underground, naturally filtered, and uncontaminated supply, Chapters VI to XII would not be interesting or applicable.

Prior to public utility commissions, valuations, rates, depreciations and records were seldom considered. Rates were established by guess or by what the traffic would bear. If revenues were insufficient, the service was apt to be deficient, taxes or bond issues made up the deficit for municipal plants or the stockholders received no dividends for private plants.

The Manual is valuable for calling attention to the importance of a sanitary water supply, to defects in methods of rate making and in the operation of plants, and has assisted in placing the water works business on a higher plane.

Revision of, or additions to, the subject matter in certain divisions is advisable, to cover the changes that have occurred since its publication. The criticisms or suggestions that have been made will enable the editors to publish a second edition of the Manual that will be of great value to operators. The contributors and editors of the Manual are entitled to much praise for their first publication.

MR. JOHN W. TOYNE:[3] In attempting the discussion of a work of this character one is confronted with so many viewpoints that a

[1] Presented before the Indiana Section meeting, March 15, 1928.
[2] Superintendent, Water Works, Richmond, Ind.
[3] Engineer, South Bend, Ind.

thorough understanding of the basis of the criticism is necessary. "Nothing just happens; Everything is the inevitable result of conditions and forces leading up to them." So with the Manual. It is a big piece of work and is the result of much time, thought and labor and is of great value to men interested in the furnishing of a potable water supply.

Any criticism I may offer is "worth just what one man thought when he wrote it and no more" and is based on his experience and observation.

The object of work of this kind is to render the greatest service to the greatest number and especially to those who would experience considerable difficulty in securing it in any other way. This raises the question as to whether we have not overshot the mark. In numbers by far the great majority of water works plants are what are termed the smaller utilities with very limited resources and unfortunately very often without technical assistance, dependent on such information as may be gleaned from such works as this under discussion, from salesmen or wherever possible.

Probably more small water systems derive their supply, either wholly or in part from wells than from all other sources, yet we find the Manual devotes 10 pages of generalities to this subject as against 60 pages on surface supplies. In the entire 10 pages not one example is given as a basis from which to determine what is really meant by the comparative terms used and thus enable the small utility operator to arrive at a conclusion in his case.

Quality of water is very adequately covered in some 40 pages and water treatment is given more than 130 pages, some 20 pages of this being devoted to the iodizing of public water supplies which is still experimental and its adoption as good practice open to question.

Distribution is well covered in about 50 pages of commendable material, all of real value.

Pumping station practice occupies some 40 pages, of which about half is devoted to boilers. My experience and observation is that, except in the larger installations, steam is becoming obsolete and that much of this space could be profitably given to other methods now considered better practice in the majority of cases.

Services, plumbing and corrosion are well treated in 20 pages while 12 pages are given to electrolysis, possibly of value, but with the better practice being followed by the power and traction companies very little trouble is really traceable to electrolysis. I feel

that, instead of rendering a service here, we are simply confusing most cases by diverting from the real cause of the trouble, whatever it might be.

Water consumption is amply discussed in 15 pages, well worth reading.

The entire section on Finance and Management, 175 pages, is excellent and makes the book well worth while were there nothing else of value between its covers.

You will note from this review that I am looking at it from the point of view of the "little fellow" without a staff of technical advisors and with only about a dollar and a quarter available to satisfy the requirements, yes demands, of his community. He, I feel, is the one the Manual should really serve.

Mr. Charles Brossman:[4] In the discussion of ground water, under strainers of gravel packed wells, some assistance might be given by amplifying or giving a brief method of testing sands for the guidance of those putting in wells, who are not experienced in this line of work.

In a large per cent of cases, contracts are let for drilling wells and the question of strainer selection and slot size of openings are left entirely to the judgment of the well driller. We have found the tendency in these cases to place too fine a strainer where gravel or sand wells are encountered and in this case the fines are not taken out to sufficient extent. In our experience we have drilled wells within one hundred feet of other wells and exactly the same strata and procured double the amount of water, simply by making the difference in the strainer.

We believe that a little more detail on this subject in the manual would be of assistance, especially to the smaller water works operators, who only occasionally get into this subject.

Motor driven pumps. For motor driven pumps, page 374, we would suggest that the question of efficiency with pumps, operating at or near full capacity, be further gone into, as, on some of the larger pumps, pump efficiencies have been found higher than those given in this paragraph. We would further suggest that the question of combined efficiency of the pump and motor be gone into. No statement is made regarding efficiency of motors.

[4] Consulting Engineer, Indianapolis, Ind.

The type and size of motor in relation to the load on the pump, as well as the speed and capacity, all have important bearing on the final efficiency.

The tendency is generally to over-motor these pumps, thereby causing a loss in efficiency. Where power factor penalties are in effect, a higher rate results for the power.

Furthermore, the matter of voltage is not discussed. This also has an effect on the rate. Further detailed statements on the above matter would be of considerable value to those who, only occasionally, buy such equipment and who may not have the full data on these details.

Deep well pumping units. On page 380, we would suggest further information on deep well reciprocating pumps. No information is given on efficiencies of such pumps by which the reader may make comparisons between this type of pump and the efficiency given on the next page for centrifugal pumps.

There is also a difference in efficiency between various types of deep well reciprocating pumps and further explanation on this might be of value.

Pumping station practice. Boilers. The comments on boilers could be brought out to better advantage in some instances. Some of the statements are somewhat confused and should be further explained or added to.

On page 350, Effect of Boiler Type on Operation—the statement is made that in the circulation of fire tube boilers, the water becomes turbulent when an attempt is made to push the boilers much above rating.

On page 351, in the second paragraph, the statement is made that fire tube boilers are generally operated from 5 to 15 per cent below rating and most of these are so built and set that they cannot be operated advantageously at much above rating.

These statements are somewhat confusing and at variance with the facts. There is no reason why fire tube boilers, with good feed water conditions and especially where the pumps are operated with surface condensers and a clean water is delivered to the boiler, should be kept below rating or at rating. Fire tube boilers can be operated even up to 200 per cent rating on peak loads and with certain improvements in tube spacing in the last few years; they are operating at such ratings without any trouble and with just as good results as other types of boilers. While it may be true that many fire tube

boilers are operated at 5 to 15 per cent below rating, this will be found equally true of many water tube boilers operated in water works plants.

On page 355, minimum setting heights are given from 8 to 10 feet for settings of horizontal return tubular boilers. Boilers so set can readily be operated up to 200 per cent rating with good feed water conditions and with good efficiency at from 125 to 150 per cent.

It does not seem consistent therefore to make the statement as given on p. 351 and then given recommendations on p. 355 which, if followed out, would give good results at considerably higher ratings.

We call attention also to the statement on page 351 that water tube boilers for steam pressure of 160 pounds or less are generally installed for operation at rating and those for steam pressure of 180 and 200 pounds are often installed for operating at ratings for 125 to 150 per cent.

We are unable to see where the question of boiler rating is limited by the steam pressure. The steam pressure has nothing to do with the rating. Water tube boilers at 160 pounds pressure can be operated at 300 per cent rating if desired and we believe the statements made on page 351 should be modified.

There is no reason why peak loads in water works plants would not be taken care of the same as peak loads in other utility plants, provided as much care is taken in the selection and installation of the units.

There is also a statement on page 351 at the last paragraph that it is sometimes found to be most economical to operate all the boilers including spares at rather low capacity.

This statement is directly to the contrary of what is found in the majority of utility plants operated at high efficiency. We believe this statement might be further explained or clarified.

Stokers. On page 358, the last paragraph, statement is made that with chain grate stokers, by equipping such stokers with forced draft and placing suitable arches over them, they are successfully used with fine sizes of anthracite, lignite and coke breeze. This statement should be amplified as forced draft chain grate stokers are very successfully used, using bituminous coal at very high ratings.

It is possible to use these stokers with forced draft at very high ratings and on the very light loads cut off the forced draft and use natural draft under certain conditions. This is done in several water works plants with good results. This type of stoker with

forced draft will burn very successfully the bituminous coals of the Middle West. We suggest that this statement on page 358 be further amplified.

Mr. Earl L. Carter:[5] I have made a general survey of Chapters XX to XXVI inclusive, of the Manual. It is my opinion that the matter as a whole, covered in this portion of the Manual, fits the water works situation pretty well. As I see it there are, of course, some minor discrepancies, but the matters set forth in the Manual pertaining to valuation and other matters with which I am more or less familiar, are quite in accordance with my ideas as to proper practices.

Starting on page 456 is a discussion of a "service charge." Theoretically, service charges are, in my opinion, proper and correct, but from a practical standpoint I am somewhat in doubt as to the advisability of making an application of such charges, due to the fact, primarily, that most consumers do not understand the service charges and are inclined quite often to criticise both the utility and the public service commission, feeling that they are being charged an unfair rate. I do not mean to infer by the above statement that I think that the service charge is wrong, but from a practical standpoint, considerable thought should be given the matter before service charges should be made a part of any rate schedule.

From a personal experience on valuations of some of the public utility properties in recent months, I have found that a few of the companies, and I am glad to say that it is by far the minority, have insisted on what in my opinion is a high and unfair appraisal for rate making purposes. I do not believe that the particular utilities which I have in mind are making their appraisals in accordance with the matters set out in the Manual.

After a rather general examination of the portion of the Manual applicable to valuation work and with which I am most familiar, it is my opinion that the Manual as now written contains a lot of helpful and valuable information. Chapters XX to XXVI, inclusive, do not, in my opinion, need any radical revisions.

Mr. I. L. Miller:[6] The Manual of Water Works Practice is the result of the efforts of committees and individuals who are recognized

[5] Chief Engineer, Public Service Commission, Indianapolis, Ind.
[6] State Board of Health, Indianapolis, Ind.

authorities in their respective fields. Much time and thought has been given to the preparation of the material which it contains. It therefore seems presumptious for any one to offer criticism without first having studied it very carefully and thoroughly. The following comments are offered only with the thought that, by supplementing and somewhat rearranging the valuable data and information contained in the Manual, it might be even of greater use to those in need of assistance of such a volume.

The Manual as stated in its preface has been "prepared primarily for the three general groups making up the active membership of the American Water Works Association. These are, first, the members of water boards and commissions, who shape the general policies of the works under their control; second, the salaried officials who manage and superintend the works; and third, the specialists who design, manage or supervise those parts of the works of a highly technical character." Manifestly a manual intended for the use of designers, superintendents and operators of water works is incomplete without a thorough discussion of health and disease as they are related to water supplies.

If the interests of health are to be served the designing engineer must have a thorough knowledge of sanitation so far as it relates to the location and construction of water works; the superintendent must understand sanitation as it relates to the operation of the works which have been constructed in accordance with good sanitary practice and, finally, the control chemist must be familiar with all phases of plant sanitation in order to interpret properly his analysis and make proper application of the results.

Important information and valuable discussions of disease, health and sanitation are contained in the sections of the Manual under the captions of "Introduction," "Collection of Water," "Quality of Water Supply" and "Treatment of Water." The chapters composing these sections, however, are very general in their treatment of the subject matter and the discussions of sanitation are largely incidental. This no doubt is due to the fact that these chapters represent the composite opinion of individuals. Certain phases of sanitation as it relates to the water supply are treated in considerable detail, while other important phases are very briefly touched upon or receive no attention whatever. For example, the protection of water sheds of surface supplies is discussed in detail; the proper protection of wells and other ground water sources receives but little

attention and the proximity of sewers to suction lines and sources of supply is not mentioned.

Citations of pertinent court cases occupy much space in several of the sections above mentioned. These citations would perhaps be more useful if given in a separate chapter and in a more condensed form.

Under the section on "Treatment of Water" one entire chapter of 17 pages is devoted to the treatment of water with iodides for the prevention of simple goiter. While this subject should not be minimized the amount of space given it is out of proportion to that of other even more important subjects.

In order to emphasize properly the importance of sanitation of water supplies and for the convenience of those using the Manual the introduction of a new section under the caption "Sanitation of Water Supplies" would seem desirable. This section should contain such new material as a competent committee deems advisable and much of that now contained in the sections on "Introduction," "Collection of Water," "Quality of Water Supply" and "Treatment of Water." Following are some suggested chapters under such a section.

1. Significance of Water Supply in Disease Incidence. This chapter should contain a summary of present knowledge of water borne diseases; a clear statement of the significance of the presence of the B. Coli group of bacteria in water and of the difficulty of isolating the typhoid bacteria.

2. Protection of Water Supplies. Sanitation of water sheds of surface supplies and of ground water supplies should be fully discussed. Subject headings might include industrial wastes, human sewage, the proximity of privies, septic tanks and sewers, the overflow of well locations, uncovered and leaky reservoirs, cross connections and other topics.

3. Methods of Analysis of Water and Interpretation of Results. No phase of sanitary control is more important than the interpretation of analytical results, consequently this chapter should represent the thought of the most able authorities. The methods should be clearly stated and the interpretation of results thoroughly discussed.

4. Jurisdiction of State and Federal Authorities and Pertinent Court Decisions. Those responsible for the design or operation of water works should know something of the liability of the owners for

disease contracted from such supplies and of the liability of those who pollute water from which public supplies may be drawn. The compilation in a brief and understandable form of court cases covering these subjects would be invaluable.

The suggestion of the introduction of a new section is prompted by the belief that important information and data on sanitation should be provided in a form easily accessible and readily understood. It is, however, difficult to determine just what should be included under such a section, since consideration of health is an important factor from the time the location of a water supply is made until the water reaches the consumer. Every phase of plant location, construction and operation is involved.

The Manual should not be made larger, but through careful deletions and condensations the size should be reduced, if possible.

MR. H. E. JORDAN:[7] In a consideration of the revision of the Manual, I think it is worth while to visualize the Manual as a book which with each edition does not attempt to cover every phase of water supply in every detail, but with each new edition takes up those phases of practices fully in which definite progress or change has taken place since the last edition. In a consideration of the portion of the Manual devoted to Water Purification Practice I am therefore inclined to assume that certain portions of the matter contained in the first edition can be presumed to be in the possession of all up-to-date water works men and can be quite reduced in their extent in the second edition, with proper reference to the fuller exposition in the first.

The section devoted to Quality of Water Supply can show the operating data in a number of plants over the country, as relates to conformance to the Treasury Standard of 1925. The general subject of Quality of Water can quite well include a discussion of the tendencies of filtered water, especially during the warm season of the year, to set up bacterial reproduction. Instances of the extent to which this reproduction goes on can be cited and there should be by all means an interpretation of its significance from a sanitary standpoint.

The section devoted to Self-Purification of Streams should take into account the very valuable published data from the United

[7] Sanitary Engineer, Indianapolis Water Company, Indianapolis, Ind.

States Public Health Service which has appeared since the first edition. The Chapter on Chlorination should include a discussion along the line of the report made by H. W. Streeter to the Association of State Sanitary Engineers entitled "Chlorination in relation to factors of safety for water filtration processes." Recent developments in super-chlorination and de-chlorination should be described.

The section on Coagulation should embody data from A. M. Buswell's "Chemistry of Water Treatment." Excess lime treatment and double coagulation should be detailed. The sections on rapid and slow sand filtration need to be condensed, but the data as to filter loading should be rewritten in the light of the contributions from the United States Public Health Service Laboratory. Developments in re-carbonation since the first edition should be carried under the chapter on Water Softening.

Developments in zeolite treatment as applied to municipal supplies should be extended and the sections on Ultra-Violet Ray treatment, Ozonization and Iodization should be materially condensed. There should be a statement as to the limitations of the degree to which finished water should be stored when this storage is likely to result in material changes in the bacterial content of the water before it reaches the consumer.

It will be seen that these suggestions are not in the tone of criticizing what was done in the first edition of the Manual. Anyone who has had the slightest contact with the work that went on prior to the appearance of the first volume realizes that its completion in as satisfactory form as it now exists was a very commendable enterprise. It is now time to consider the changes which have gone on in the art of purification since the first edition was issued and see that those things which are worth while are set out in the way that brings them to the attention of men engaged in public water supply work.

Mr. W. C. Mabee:[8] Most of these gentlemen today have discussed the Manual from the angle with which they are most familiar and that is where I am going to interject a few remarks in regard to checking on water. We study up on a subject when it has been assigned to us and sometimes we do not study up until that time comes because we are so very busy with our every day problems. I am going to talk on the subject of "Unaccounted for Water."

[8] Chief Engineer, Indianapolis Water Company, Indianapolis, Ind.

The Manual is a valuable source of information. I did not find everything a water works man would want to know in it, as much has been left unmentioned. There is a tabulation which shows the amount of water that is accounted for in a number of cities and in some of those tabulations show quite a number of cities accounting for 100 per cent of the water that enters their systems. When you think about that it sounds fishy and I know you men will agree with me that it is fishy. I suggest there is room for improvement in the Manual in dealing with the subject of "Unaccounted for Water."

A Member: There is one chapter that is very interesting to me personally and I think it is a subject that should be given considerable attention, although as yet it is in the experimental stage. Some suggestions have been made to cut out the chapter on iodization, but to me it is very interesting because in my family there has been a case of goiter that was caused by the water supply. I found this material very valuable.

Another thought on the question of services. Every water supply has services and there are different ways of making these connections.

Another suggestion which I would make is a greater use of figures and diagrams. There are many cases where words are used that would be more intelligible, if taken care of by pictures, diagrams and figures.

DISCUSSION

TEST FOR CHLORO-PHENOLIC TASTES

The test for chloro-phenolic tastes offered by Mr. Sperr and his collaborators is admirably designed.[1] It is believed that, in one respect, it can be improved upon so as to fulfil more satisfactorily the end which the authors had in view. It is possible that a misconception exists as to the rôle played by chlorine in causing taste. The "iodoform" taste may be due to bromophenols instead of chlorophenols and possibly, in very rare instances, to iodophenols. The action of the chlorine is to liberate bromine from the bromide naturally present in the water. The combination between bromine and phenol is one of the best known reactions of phenol and those familiar with the bromophenols will easily identify their persistent odor with the "chlorophenolic" odor.

We should expect, therefore, the addition of bromine to say 0.075 to 0.125 p.p.m. instead of chlorine to 0.3 p.p.m. to prove much more satisfactory in actual work. Precaution has to be taken not to use too much bromine, for an excess appears to kill the taste the same as chlorine.

It is true that, as pointed out by Professor Kolthoff in a private communication, commercial liquid chlorine may contain much bromine; it may, therefore, yield some "iodoform" taste with phenol at high dilutions. But the chlorine attacks the bromophenol and if in sufficient excess and given sufficient time will eliminate the "iodoform" taste (superchlorination effect).

Perhaps a trace of sulphur dioxide could be used for debromination instead of the boiling.

Our work has not reached the stage at which we can put forward quantitative figures. We offer these suggestions with all reserve in the hope that those using the test may find them helpful.

FRANK HANNAN.[2]
JOHN R. BAYLIS.[3]

[1] Journal, May, 1928, page 605.
[2] Water Department, Toronto, Can.
[3] Department of Public Works, Chicago, Ill.

EDITORIAL COMMENT

Fire Hazards and the Water Supply

Within the past four months, two conflagrations have occurred in the United States which have definite significance for the water works fraternity. Both of these were of tremendous proportions and both were preventable. The first refers to the Fall River, Massachusetts, fire, starting in the early evening of February 2, 1928. It destroyed virtually six blocks of the business center of Fall River with a total loss estimated by the National Board of Fire Underwriters at something over $6,000,000, of which about $4,000,000 were covered by insurance. The replacement costs, however, probably will be in the neighborhood of $10,000,000 or more.

The conflagration is the subject of a detailed report[1] issued by the National Fire Protection Association. The report is an instructive summary of the assets and failures of fire protection and prevention measures of all types. Among these the water supply facilities at Fall River showed up remarkably well. The report demonstrates clearly the vast importance in water supply design and maintenance of adequate storage capacity, complete pumping equipment, satisfactory curb pressures and large sized supply mains. As a matter of fact, the sole deficiency in the water supply system reported during the fire was that of possible shortages of water due to the somewhat limited capacity of the 24-inch supply main for the heavy demands made upon it. During twelve hours at the height of the fire, the total pumpage varied from 940,000 to 980,000 gallons per hour.

In view of the fact that fire apparatus was used during this fire from neighboring towns, in some cases 50 miles away, and that 32 motor pumpers were actually in use from 22 neighboring cities, the necessity and value of standard hose couplings on municipal fire hydrants in Fall River and nearby cities were amply demonstrated. The National Standard hose coupling threads were established about four years ago in Fall River and nearby cities. All of the cities

[1] The Fall River Conflagration, February 2–3, 1928, National Fire Protection Association, Boston, Mass.

sending apparatus to Fall River, with the exception of one, were able to connect directly with the Fall River hydrants and hose. The single exception sent its companies provided with adapter couplings.

The report on the water supply facilities is gratifying in that it concludes that "Considering the very heavy drafts on the system by the fire apparatus and the numerous broken services in the buildings, which ran until the following morning before emergency crews from the water works could reach them to shut off the water, it would seem that the water supply stood up under the strain fairly well."

The report further concludes that the great extent of loss was due to the fact that the area burned was covered with buildings of inferior construction, with practically no effective fire division walls and little fire resistive construction. Sprinkler buildings, fire walls and wall openings properly protected with tin clad shutters and wire glass windows, were instrumental in checking the spread of the fire in a number of directions. Automatic sprinklers adjacent to window openings and open sprinklers were of enormous aid in preventing fire spread.

An illustration of a totally different state of affairs is that of the Crisfield, Maryland, fire, on March 29 and 30, 1928. Crisfield is a community of some 4100 persons. A fire started in a local theatre. It destroyed 90 buildings, an area of 4 blocks surrounding the municipality's busiest corner and caused an estimated monetary loss of $1,000,000. The fire lasted throughout the night and was largely subdued after a shifting wind had made it possible for the Crisfield fire department and the fire departments from five other cities to control the blaze. It is probable that, if the wind had not shifted, an area many times in size would have been wiped out.

This catastrophe has considerable significance to the water supply superintendent. The water storage facilities were less than 175,000 gallons. Auxiliary driving equipment for the municipal water pumps was lacking, so that when the electric lines furnishing power to the pumping station fell, the water works pumping plant was completely out of service. The distribution system was of small size and recourse to pumping from nearby creeks was essential. The 120,000 gallons of water remaining in the municipal standpipe, when electric power was shut off from the plant, were exhausted in a few minutes. Water was obtained from a creek approximately one-third of a mile from the scene of the fire and was relayed to the fire by the engines through

the municipal distribution system. The area burned contained a number of properties of wood of distinct structural hazard and built in many instances in solid block.

The importance of these two instances of destruction by fire is both in contrast and in similarity between the different sets of conditions. In contrast, one community was adequately supplied with fire fighting facilities, while the other was deficient. In similarity, however, both communities, large and small, contained extremely hazardous areas which might have been more adequately protected through modern building laws.

That water supply facilities must be brought to the maximum point of fire fighting efficiency, even in very small towns, is no longer debatable, even upon financial bases. Dryden,[2] for example, has recently called attention to the construction in Salisbury, Md., of a new and improved water supply system for a total expenditure of $450,000 for a population of 12,000. Before the construction of these water supply facilities, the fire insurance deficiency charge for water supply alone was 19.6 cents per $100. After the water supply was built in accordance with the usual Fire Underwriters Association's requirements, this water supply deficiency was reduced to 1.7 cents per $100. The financial objection to water supply construction disappears when it is noted that, in the above system, the annual fixed charges on the outstanding water bonds are $27,000, whereas the annual savings in fire insurance premiums on non-residential properties alone are now estimated at $40,000.

Similarly, Munroe,[2] in discussing the figures presented by Dryden, points out a similar reduction of from 55 to 30 cents per $100 in a community in Maryland of 4000 population, following upon and due to the installation of an adequate water supply system.

The taxpayer and water consumer have everything to gain and nothing to lose by installing modern water supply systems adequate both for domestic and fire fighting purposes.

ABEL WOLMAN[3]

[2] Paper before Maryland Water and Sewerage Association, April 10, 1928.

[3] Editor-in-Chief, Journal of the American Water Works Association; Chief Engineer, Maryland Department of Health.

SOCIETY AFFAIRS

FLORIDA SECTION

The second annual meeting of the Florida Section was held at Orlando, April 3 and 4, 1928.

The meeting opened at the Tuesday luncheon which was the courtesy of the Orlando Chamber of Commerce, at which time 65 plates were served. In the afternoon the business session was held and the following officers were elected for the coming year: Chairman, A. P. Michaels, of Orlando; Vice-Chairman, R. W. Reynolds, West Palm Beach; Directors: C. C. Brown, Gainesville; F. J. Stewart, Hollywood; F. W. Lane, St. Petersburg; Ben Tippens, Daytona, Beach and O. Z. Tyler, Jacksonville; Secretary-Treasurer, E. L. Filby, Jacksonville.

The Tuesday evening banquet was given in honor of J. E. Gibson, President, American Water Works Association. Mr. Gibson gave a very pertinent address on the subject of "Not Good if Detached"—stressing the fact that every waterworks superintendent or operator should be a member of the Section of American Water Works Association nearest to him. Speakers at the banquet included, Malcolm Pirnie and F. W. Weir, Assistant Engineer of Georgia State Board of Health.

The Wednesday program was given according to schedule. By Wednesday noon the register had reached its peak of 114 and an enjoyable luncheon was served at the Orlando Utilities Commission Filter Plant (Municipal) through the courtesy of the Utilities Commission.

At the Manufacturers Banquet on Wednesday evening Jacksonville was selected for the next meeting place for the 1929 meeting.

Stenographic notes were taken of the entire meeting for the two days.

The following papers were presented during the session.

"Laboratory control of water purification." F R. Georgia. Discussed by A. P. Black, C. C. Humphries, M. A. Norris and Charles Morgan.

"Private Operation of Small Plants." G. C. Hyde.

"Underwriters Requirements for Fire Protection Purposes for Small Plants." A. M. Schoen.

"Automatic Control of Electrical Pumping Devices." R. B. Roberts.

"Sarasota's Automatic Water Plant." J. R. Brumby, Jr.

"An Electric Automatic Iron Removal and Pumping Station." P. P. De Moya.

"Determination of Equitable Water Rates." Malcolm Pirnie.

"Cost Accounting for Water Works." R. H. Smith.

"Railroad Water Supply."

"Chemical Quality." W. H. Hobbs.

"Mechanical Features." H. P. Boone.

Round Table Discussion—"Public Relations." Led by R. W. Reynolds.

Question Box.

E. L. Filby,
Secretary-Treasurer.

MONTANA SECTION

The third annual meeting of the Montana Section, held at Lewistown, March 8, 9, and 10, 1928, was a repetition of the success of the preceding gatherings.

Trips to the city's big springs, flowing some 62,720 gallons of water per minute; to the plant of the Three Forks Portland Cement Company, and to other points of interest to technical men aided in the entertainment of the delegates.

Three legislative matters of interest to water works operators were of chief importance on the floor of the convention.

The section went on record as favoring the passage of a bill in the state legislature which would create in all cities and towns owning and operating municipal water systems, a board of water commissioners functioning independently, as far as possible, from the local council.

Due to the great need of closer coöperation between fire fighting organizations, the water works superintendents, who in many cases are members of their local fire departments, voted to support an attempt to standardize all hose connections in the state, making them conform to the National (American) Standard Fire-Hose Coupling Screw Thread. The attempt will be made through the purchase of

sets of standardizing or salvaging tools by the state and their use by agents of the state fire marshall's office in coöperation with the local fire department officials.

The question of a state plumbing code and examining board gained the support of the whole delegation who voted to back an attempt to secure the necessary legislation.

There were in attendance 18 active members of the local section, 10 active or associate members from other localities, 10 others representing water works equipment houses, and several who through their state or local positions were interested in the proceedings, 47 in all being registered.

Mr. Theo. Leisen, past president and member of the Executive Committee, A. W. W. A., now residing in and directing the activities of the Municipal Utilities of Omaha, was in attendance and on the program. The Section extended a vote of thanks to the parent Association for delegating Mr. Leisen to attend the sessions as its representative.

Mr. Jos. M. Schmit, city engineer of Lewistown, Montana, was chosen president for the coming year with Emil Sandquist, city engineer, Havre, and H. B. Foote, state sanitary engineer, Helena, supporting him as vice-president and secretary-treasurer, respectively.

A banquet sponsored by visiting equipment representatives, and enjoyed by the whole delegation, concluded the activities of the annual conclave. Great Falls, Montana, will be host to the fourth annual convention in 1929.

H. B. Foote,
Secretary-Treasurer.

ABSTRACTS OF WATER WORKS LITERATURE[1]

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

Rapid Test for Water Content of Damp Aggregates. Tappan Collins. Eng. News-Rec., **99**: 604, 1927. Brief description of method for determining water content which consists in mixing a saturated salt solution with the aggregate and determining the specific gravity of the resulting solution with a hydrometer, contained in a syringe, graduated in gallons of free water per cubic foot of aggregate. No correction for absorbed water is necessary.—*R. E. Thompson (Courtesy Chem. Abst.).*

Placing 36-inch Pipe in 150-foot Sections Saves Time and Cost. Eng. News-Rec., **99**: 603, October 13, 1927. Brief data on construction of recently completed 17-mile El Capitan pipe line from Riverview pumping plant to San Diego, Cal., which consists of 36-inch lock-bar steel pipe, ½ inch thick, wrapped with soilproof covering and delivered along trench in 30-foot lengths. Five 30-foot sections were riveted together and the 150-foot unit (weighing 18 tons) was then lowered into ditch by 2 derricks mounted on crawlers.—*R. E. Thompson.*

Pondage a Factor in Spillway Design. Eng. News-Rec., **99**: 606–7, October 13, 1927. Discussions of methods for spillway analysis by J. C. Stevens, W. S. Pardoe and Melvin D. Casler.—*R. E. Thompson.*

Diversion Dam Consists Chiefly of Collapsible Units. A. Kanekeberg. Eng. News-Rec., **99**: 769, November 10, 1927. Brief illustrated description of small diversion dam of Public Service Co., on Platte River in Colorado consisting of reinforced-concrete apron with steel sheet piling collapsible cutoff wall.—*R. E. Thompson.*

Long Water Tunnel in Great Britain. Eng. News-Rec., **99**: 795, November 17, 1927. Brief description of 16-foot tunnel 16 miles long through Ben Nevis being constructed as part of supply line for hydro-electric plant.—*R. E. Thompson.*

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[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

Winter Construction Methods and Plant. C. S. Hill. **V. Winter heating of concrete materials and mix.** Eng. News-Rec., **99:** 506–10, 1927. **VI. Handling and placing concrete in winter.** Ibid., 544–8. **VII. Protecting winter placed concrete in heavy sections.** Ibid., 597–9.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Turbine Efficiency 94 Per Cent Over Wide Range of Head. Eng. News-Rec., **99:** 628, October 20, 1927. Brief data on two hydraulic trubines recently installed in Melones Power House of Pacific Gas and Electric Company, on Stanislaus River, which have attained efficiency of approximately 94 per cent at heads ranging from 160 to 220 feet.—*R. E. Thompson.*

Steel Penstock Design By a Graphical Method. Peter Bier. Eng. News-Rec., **99:** 629–34, October 20, 1927. Graphical method proposed.—*R. E. Thompson.*

Flood Protection Work Started at Beardstown, Ill. Eng. News-Rec., **99:** 588–9, October 13, 1927. Illustrated details of flood protection work at Beardstown on Illinois River.—*R. E. Thompson.*

Further Data on Failure of the Gros Ventre "Dam." Eng. News-Rec., **99:** 600–1, October 13, 1927. On June 23, 1925, a landslide swept earth and rocks down mountain side and blocked Gros Ventre river channel, forming dam about 1½ miles thick through base and some 4000 feet long on top. No fears were entertained as to safety of natural barrier, but on May 18, 1927, a portion of the material gave way and was carried out by impounded water with great suddenness. Event is important in regard to grading of materials used in earth dams. Conditions obtaining described.—*R. E. Thompson.*

Carbon Dioxide Treatment at St. Louis Water Works. A. V. Graf. Eng. News-Rec., **99:** 643, 1927. Two plants for producing CO_2 will be installed at St. Louis for preventing carbonate deposition following softening with lime; one of 40,000-pound per day capacity to treat 160 million gallons per day at the old works and one of 20,000-pound per day capacity to treat 80 million gallons per day at the new plant. Each plant will consist of a gas producer burning coke; combined washer, scrubber, and drier; gas burner; compressor or blower; and necessary gages. Trouble from carbonate deposits has been much less since the adoption of filtration. The deposit on the filter sand amounts to 17 per cent of the filtering medium.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Expansion and Contraction of Welded Gas Lines. Eng. News-Rec., **99:** 635, October 20, 1927. Data from paper by F. M. Lege, Jr., describing construction of 215-mile line made up of pipe 14, 16, and 18 inches in diameter. Most satisfactory method of securing and holding slack in large lines is by laying line on top of 12- to 24-inch blocks spaced 100–200 feet apart. Line may then be lowered into ditch during early afternoon with skids distributed where blocks were formerly placed. It can then be covered between blocks and the

blocks removed during night, allowing line to settle into ditch sufficiently to be covered. Unless skids hold up line at regular intervals, slack secured by use of blocks will crawl ahead and be lost. Amount of slack is determined by temperature variations. Due consideration should also be given to elasticity of the steel, and where line crosses long steep hills great care should be taken to be sure that compression exists on both sides of hill. Use of expansion joints or couples is unncessary and would only be source of trouble. Practice indicates that with only fairly good weld no trouble will be experienced from expansion and contraction with temperature variation of as much as 60°.—*R. E. Thompson.*

Sink Hole Topography Study for Sewage Disposal. J. E. Lamar. Eng. News-Rec., **99**: 642–3, 1927. Study of underground flow in connection with proposal to dispose of sewage of subdivision of Alton, Ill., by emptying into conveniently located sink hole, indicated that sewage thus discharged would enter Mississippi River at point above water works intake of Alton.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Use of Returned Sludge Speeds up Water Softening Reactions. A. W. Bull. Eng. News-Rec., **99**: 748, November 10, 1927. Laboratory tests at Columbus and Pittsburgh indicated that use of returned sludge considerably hastens water softening reactions. Tests at Columbus showed that agitation for 19 hours was necessary to reduce soap hardness to 66 p.p.m. by lime-soda method, while same reduction was secured in 2 hours by addition of 50 cc. sludge per gallon of water with the softening chemicals, and in 1 hour by addition of 100 cc. sludge. Best results were secured with sludge concentration of 15,000 p.p.m. Fact that final alkalinity and causticity were not increased by increasing amount of sludge shows that results were not due to presence of unused chemicals. At Pittsburgh, with water unusually high in magnesium sulfate, addition of 7100 p.p.m. sludge produced good results. Water was apparently softened as easily at 0°C., as at 10°C., and in both cases better results were obtained than could have been effected at 30°C., without use of sludge. Further advantage is increased efficiency of sedimentation when sludge is added.—*R. E. Thompson.*

Modification of Bell's Bund System Simplifies River Control. P. Claxton. Eng. News-Rec., **99**: 720–2, November 3, 1927. Description of method of river control known as Bell's Bund System, widely used in India for protection of embankments at river crossings. Its essential feature consists in using still-water pockets to keep swift waters of main stream from reaching banks needing protection by construction of earth bunds.—*R. E. Thompson.*

Wood Stave Outfall Sewer Encased with Concrete after Bands Fail. W. C. Hammatt. Eng. News-Rec., **99**: 686, 1927. An 18-inch redwood stave outfall sewer laid in El Cerrito, Cal., in 1905 through a salt marsh which was drained and reclaimed in 1913 developed an occasional leak in 1920. Examination showed the wood to be in perfect condition but that steel banding in many cases had failed due to corrosion. The pipe has now been encased in 2 inches

of concrete, which, it is believed, will extend the life of the pipe 20 years.—*R. E. Thompson (Courtesy Chem. Abst.).*

Water Pumped into Reservoirs for European Plants. OREN REED. Eng. News-Rec., **99**: 722–3, November 3, 1927. Data on several power plants in Europe.—*R. E. Thompson.*

Sewer Tunneling by Day Labor at St. Paul, Minn. WM. N. CAREY. Eng. News-Rec., **99**: 709–11, November 3, 1927. Illustrated description of construction of concrete lined tunnel, 7 feet and 8 feet horseshoe section, 50 feet below surface, through mixture of clay and sand, 75 per cent of which was wet enough to be hazardous.—*R. E. Thompson.*

New Design Features in Willwood Diversion Dam. IVAN E. HOUK. Eng. News-Rec., **99**: 660–4, October 27, 1927. Illustrated description of design and construction of Willwood diversion dam on Shoshone River irrigation project in northern Wyoming. Dam, which was built by Bureau of Reclamation in 1922–3, is concrete gravity overflow structure 320 feet long, surmounted by steel truss highway bridge. Canal headworks section, 70 feet above foundation, was made integral part of dam, diversion water being carried through longitudinal tunnel within structure.—*R. E. Thompson.*

Description of Water Treatment at Indianapolis. HARRY E. JORDAN. Eng. News-Rec., **99**: 762–4, 1927. A detailed description of the plant for purifying the water supply of Indianapolis, which is obtained from the White River. Construction of a sedimentation basin and improved operating methods enabled the rate of filtration through the slow sand plant constructed in 1904 to be increased from 2.6 to 6.2 million gallons per acre per day. A coagulant is employed when the suspended matter exceeds 30 p.p.m. A 12-million gallon per day rapid sand plant, consisting of six 2-million gallon per day units and twin coagulation basins, was placed in operation in 1926. The alum dosing equipment consists of a hydrometer-controlled tank for preliminary adjustment, the final concentration being controlled with the aid of conductivity apparatus. Under certain raw water conditions prechlorination is employed, and Cl_2 is applied at all times to the effluent to maintain a residual Cl_2 content of 0.1 p.p.m. The maximum turbidity of the effluent during the first year of operation was 0.3 and the average 0.17 p.p.m. The average bacterial count at 37° after chlorination was 7 per cubic centimeter, and B. coli was present in only 0.6 per cent of 10-cc. samples examined.—*R. E. Thompson (Courtesy Chem. Abst.).*

Mississippi River Commission Severely Criticised. ARTHUR E. MORGAN. Eng. News-Rec., **99**: 641, October 20, 1927. Criticism of work of Commission, particularly with regard to rejection of reservoirs as means of flood control. —*R. E. Thompson.*

Timber Bulkhead Protects Levee in Louisiana. Eng. News-Rec., **99**: 665, October 27, 1927. Brief description of bulkhead wall of piles and sheeting

constructed on Mississippi River front at Arabi, La., to protect levee grade increase.—*R. E. Thompson.*

Stream Pollution and Industrial Wastes in Wisconsin. Eng. News-Rec., **99**: 664, October 27, 1927. Data from report of survey conducted by State Board of Health and the Conservation Commission, July 1, 1925 to December 31, 1926. Survey was authorized by legislature in 1925, which appropriated $10,000 annually to enforce statutes in regard to stream pollution. Data on Mississippi River are given. Conclusions regarding treatment of industrial wastes include: (1) Pea canneries: Application of 3¾ pounds ferrous sulfate and 7½ pounds lime per 1000 gallons of waste, followed by satisfactory sedimentation, will reduce oxygen demand approximately 75 per cent. Cost of equipment for maximum discharge of 100,000 gallons per day ranges from $2000 to $2800, and operating costs from $13 to $15 per day. Removal of coagulated solids is essential to prevent overloading of sewage disposal plants during canning season. (2) Paper mills: Suitable save-all equipment will economically reduce waste of paper-making material to about ½ pound per 1000 gallons of waste. Aërating and impounding sulfite liquors will reduce oxygen demand 50–75 per cent. (3) Knitting mills: In preliminary treatment, lint and grease constituents, which interfere with normal operation of sewage disposal plants, can be removed by fine mechanical screening and iron sulfate and lime treatment. (4) Combined sewage wastes: Experiments at Waupun, Wis., on city sewage combined with wastes from dye-works and pea and corn canneries, indicated that either activated sludge process or preliminary sedimentation, chemical treatment, and aëration would yield satisfactory effluent. Plans for latter have been approved and construction authorized.—*R. E. Thompson.*

European River-and-Harbor Laboratories Revisited. John R. Freeman. Eng. News-Rec., **99**: 873–5, December 1, 1927. Data given on laboratories visited in Germany, Italy, and Switzerland. Important work could be accomplished in similar laboratories in United States. Laboratories are of 3 types: (1) Those dealing with river control and harbor work. (2) Those dealing with hydraulic power problems, study of turbines, centrifugal pumps, etc. (3) Those for solving naval problems.—*R. E. Thompson.*

New Water Supply for Kansas City to be Completed in 1928. Eng. News-Rec., **99**: 719–20, November 3, 1927. Description of progress on new 100-m.g.d. supply system of Kansas City, Mo. Purification works for treatment of Missouri River water consist of 3 traveling screens of ⅜-inch mesh, 4 preliminary settling tanks of combined capacity of 16 m.g. equipped with Dorr clarifiers, 2 tanks of combined capacity of 2 m.g. for mixing with lime and alum, 5 coagulation basins of 51 m.g. total capacity, 24 rapid sand filters and chlorination equipment. Data included on construction of Missouri Valley concrete-lined tunnel, which is 7½ feet in diameter and 15,570 feet long. Gas encountered was serious difficulty, as result of which compressed air had to be substituted for electrical equipment, lighting being obtained by cap lights. Ordinary 40 per cent gelatin dynamite caused ignition of gas. Adoption of Gelobel, which is about same strength but has very fast flame, eliminated this difficulty.—*R. E. Thompson.*

Semicircular Arch Dam Model Tested in Italy. C. Guidi. Eng. News-Rec., **99**: 668–9, October 27, 1927. Illustrated description of test of arch dam 17 feet in span and 16 feet high, which, by ingenious experimental arrangement, was carried out under head far exceeding height of structure. Observations on elastic deformations agree closely with those made on Stevenson Creek Dam.—*R. E. Thompson.*

Rotating Chains Effectively Clean Pipe in Oil Field Service. Eng. News-Rec., **99**: 685, October 27, 1927. Removal of protective coatings, rust, etc., is effected by home-made device consisting chiefly of belt driven disk to whose face a number of short pieces of chain are firmly attached by one end. When disk is rotated chains stand out like spokes of wheel, projecting beyond edge of disk, and tap pipe with rapid succession of light hammer blows. Pipe section to be cleaned is laid on car carrying roller device so arranged that pipe can easily be rotated by hand as car moves to and fro within reach of chains.—*R. E. Thompson.*

Work of Mississippi River Commission Outlined. C. W. Kutz. Eng. News-Rec., **99**: 670–3, October 27, 1927. Review of history and limitations of Commission and outline of studies on extensive flood-control program based on effects of 1927 flood.—*R. E. Thompson.*

Flood Rainfall in New England. H. K. Barrows. Eng. News-Rec., **99**: 796–8, November 17, 1927. Data given on rainfall in New England on November 3–5, 1927, which resulted in flood.—*R. E. Thompsoh.*

River Conditions in Flood Area in New England. Eng. News-Rec., **99**: 798–9, November 17, 1927. Data given on flood flow of rivers as result of storm of November 3–5, 1927.—*R. E. Thompson.*

Flood Effect on Sharon Dam on the White River. R. R. Marsden. Eng. News-Rec., **99**: 799, November 17, 1927. Brief data on damage by flood.—*R. E. Thompson.*

Testing Welds Under Field Conditions. Eng. News-Rec., **99**: 800, November 17, 1927. Recent investigations have shown that in bending test, measurement of elongation rather than angle of bend is more accurate indication of quality of weld. Gage marks are made on either side of weld and specimen is bent to first sign of cracking, after which elongation may be easily measured with flexible scale. Elongation should be about 20 per cent for weld in mild steel plate. Portable machine has been developed to test specimens cut from welds in a line.—*R. E. Thompson.*

Difficulties Met With in Welding River Crossing of Pipe Line. Eng. News-Rec., **99**: 847–8, November 24, 1927. Brief description of construction of 2 welded 10-inch gas pipe lines across Mississippi River. Line was arched upstream to put it under compression, 1500 feet of pipe being used in 1300-foot crossing.—*R. E. Thompson.*

Ingenious Form-Handling on Covered Reservoir. Eng. News-Rec., **99**: 838–40, November 24, 1927. Illustrated description of construction of 2 covered concrete reservoirs at Providence. Structures are familiar type depressed reservoir: slab floor, columns on raised pedestals, flat roof with drop panels over columns and reinforced walls of uniform thickness from top to bottom, tied into both roof and floor. One reservoir, Neutaconkanut, is 400 × 600 feet and other, Longview, is 200 × 320 feet.—*R. E. Thompson.*

Government to Begin Flood Study. Eng. News-Rec., **99**: 810, November 17, 1927. Letter by Engineering News-Record to Secretary of Interior urging comprehensive flood studies, and reply by HUBERT WORK to effect that study of New England flood is under way and that broader flood studies will be undertaken.—*R. E. Thompson.*

Flood Study and Flood Precautions. JOHN R. FREEMAN. Eng. News-Rec., **99**: 810, November 17, 1927. Discussion with special reference to New England flood.—*R. E. Thompson.*

Some Aspects of New England's Greatest Flood. JOHN W. SHAVER. Eng. News-Rec., **99**: 841–5, November 24, 1927. Data on flood of November, 1927. —*R. E. Thompson.*

Power-Operated Pipe-Straightening Device Used in Oil Fields. Eng. News-Rec., **99**: 846, November 24, 1927. Brief illustrated description of machine for straightening pipe up to 10$\frac{3}{4}$-inches outside diameter and wall thickness of $\frac{1}{2}$ inch. Fundamentally, scheme consists of placing pipe beneath steel lever arm operated by compressed air and mounted in heavy concrete setting. —*R. E. Thompson.*

Additional New England Rainfall Records. Eng. News-Rec., **99**: 888, December 1, 1927. Additional records for rainfall on November 2–4, 1927.—*R. E. Thompson.*

Heat Changes during Setting of Alumina and Portland Cements. A. A. JAKKULA. Eng. News-Rec., **99**: 955–6, 1927. Results of experiments carried out to determine amount of heat developed and temperature reached during setting are presented graphically. The conclusions formed are as follows: (1) Specimens made of neat cement and confined to prevent heat escape, reached temperature above 100°. (2) A decrease in the richness of the mix reduced the temperature rise. (3) Alumina cement specimens reached temperature 4 times that of similar portland cement specimens. (4) The rise in temperature of the alumina cement specimens was sudden, a rise of over 100°F., occurring in approximately 15 minutes in every instance. (5) A high initial temperature causes quick settling of an alumina cement mix. (6) Alumina cement specimens generated over twice as much heat as similar specimens of portland cement. (7) With an initial temperature below 80°F., the temperature of alumina cement concrete will start to rise in approximately 5 hours.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Emergency Water Supply Relief in New England's Flood Area. Eng. News-Rec., **99:** 889, December 1, 1927. Details given of restoration of water supply of Waterbury, Vt., as typical example of emergency and final relief.—*R. E. Thompson.*

New Power Plant Replaces Old Waterwheels. Eng. News-Rec., **99:** 908–11, December 8, 1927. Illustrated description of hydro-electric plant being constructed on Connecticut River at Bellows Falls, Vt., by New England Power Association.—*R. E. Thompson.*

New England Flood Rainfall Surpassed in Central States in 1913. C. H. Eiffert. Eng. News-Rec., **99:** 974, December 15, 1927. Data given showing that New England flood rainfall in 1927 was exceeded during Ohio storm of 1913, maximum 2- and 1-day falls over 4000 miles area being 8.0 and 5.8 inches for Ohio storm and 6.4 and 5.4 inches for New England storm.—*R. E. Thompson.*

Bronze-Weld Joint Develops Full Strength of Cast Iron Pipe. Eng. News-Rec., **99:** 880–1, December 1, 1927. Results of investigation by United States Cast Iron Pipe & Foundry Company, and Lunde Air Products Company. Fractures occurred in iron next to weld with collar type of joint, while with vee type failure occurred along edge of weld. Because of high shear strength of bronze adhering to cast iron and the doubtful tensile adhesion, collar type of joint has been used practically exclusively up to present time. Mechanical design of collar joint necessarily causes stresses to concentrate on either side of joint. Early abandonment of vee type joint was due, not to defects in its mechanical design, but to improper preparation of pipe ends for welding. Finished surface of cast iron when machined is difficult to tin and as result bronze adheres poorly. Pioneer investigators were unaware that by searing or annealing machine bevels to bright red, tinning becomes easy. Bending tests made on full size pipe sections welded with vee joint indicated efficiencies of 83 and 79 per cent respectively for de Lavaud and sand-cast pipe. Failure occurred in every case along vee. By redesigning this joint and adding shear area the "shear vee" joint (illustrated) was developed. In tests of the joint, pressures of 27,800 and 24,500 pounds per square inch were reached before failure occurred.—*R. E. Thompson.*

Chinese Flood Problems Similar to Those of Mississippi. G. W. Olivecrona. Eng. News-Rec., **99:** 875–6, December 1, 1927. Description of flood problem of Kwangtung, China, which is similar in many respects to Mississippi problem.—*R. E. Thompson.*

Tests Show Shrinkage Effect of Calcium Chloride in Concrete. A. S. Levens. Eng. News-Rec., **99:** 912, 1927. Tests of concrete in which had been incorporated 1–6 per cent $CaCl_2$, showed that shrinkage is greatly increased when $CaCl_2$ is added, particularly with the larger amounts. Considerable increase is apparent with the optimum amount of $CaCl_2$ (2–4 per cent based on weight of cement).—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Reconstructing Croton Aqueduct High Bridge. Eng. News-Rec., **99**: 864–6, December 1, 1927. Illustrated description of reconstruction of High Bridge, New York's Roman-type masonry arch aqueduct across Harlem River, which is being carried out in interests of navigation.—*R. E. Thompson.*

Right to Underground Water Sustained by Court. Daniel W. Murphy. Eng. News-Rec., **99**: 926, December 8, 1927. Superior Court of Maricopa County, Arizona, recently handed down decision in which right of well owners to flow of water in underground stream is recognized regardless of inability to locate boundaries of underground channel. Suit was brought by subsidiaries of Goodyear Tire and Rubber Co., against Maricopa County Municipal Water Conservation District No. 1, et al. Defendants had constructed dam on Agua Fria River forming reservoir in which waters of stream are stored and used for irrigation. Plaintiffs contended that water absorbed in stream bed was source of supply for their wells. Finding was that impervious bed and banks are not essential to an underground stream, and that the less permeable materials which border an underground stream may be regarded as forming its bed and banks.—*R. E. Thompson.*

Five Cableways 3100 Feet Between Masts for Nile River Dam Work. Eng. News-Rec., **99**: 932, December 8, 1927. Brief description of 5 aërial cableways, 182 feet high, to be used for transportation of men and materials during construction of Nag Hammadi Barrage across Nile River.—*R. E. Thompson.*

Study of Sewage Settling Tank Design. C. H. Capen, Jr. Eng. News-Rec., **99**: 833–7, 1927. Conclusions drawn from a study of a number of sewage settling tanks are given. The term efficiency rating (expressed as a percentage) is used to denote the ratio: flowing-through period/detention period. In practice this varies from about 50 per cent in the case of some well designed tanks to 20, or 15, or even less, in the case of others. The flowing-through period was determined by the salt method, the theory of which is discussed. The salt concentration in the effluent was first determined by titration and later a conductivity method was devised. When a dye was introduced simultaneously with the salt, the appearance of deepest color at the outlet usually agreed closely with the peak chloride concentration but the color always disappeared before the last trace of chloride. Recommendations as to design are included. By using reasonable care it is believed that an efficiency rating of 30 per cent may be obtained. The theory is applicable to any settling problem, such as water coagulation. [Those interested will find instructive discussion of the application of salt method to determination of flowing through time in paper by Guy T. P. Tatham in J. Soc. Chem. Ind. **35**: 711–5, July 15, 1916.—Abstr.].—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Tunneling Methods in Plastic Clay at Detroit. Eng. News-Rec., **99**: 948–54, December 15, 1927. Illustrated description of extensive tunnel program in progress at Detroit which comprises nearly 10 miles of 14- and 12-foot tunnel at depth of 60–100 feet. Lining is of concrete, with grouting to fill voids. Material through which tunnel is being driven consists chiefly of

varieties of clay interspersed with sand pockets, and construction methods include tunneling in free air and under light pressures, and tunneling by hand and by machine boring. New tunnel is part of aqueduct system which includes for immediate construction a 4500-foot intake tunnel under Detroit and for future construction a second undercity tunnel. Ultimately each of land tunnels will have, at inland end, filtration works and pumping stations. Whole system will provide additional supply of 900 m.g.d.—*R. E. Thompson.*

Study of Sewage Settling Tank Design. Eng. News-Rec., 99: 1054–6, 1927. Discussions of article of C. H. CAPEN, Jr., by RICHARD H. GOULD, F. E. DANIELS and H. L. THACKWELL and reply by C. H. CAPEN, Jr.—*R. E. Thompson (Courtesy Chem. Abst.).*

Hydromineral Springs. Physico-Chemical Determinations to be Carried Out in the Field. F. TOUPLAIN. Ann. fals., 19: 396–411, 467–80, 1926. From Chem. Abst., 21: 370, February 10, 1927. Description of determinations which must be carried out to ascertain normal conditions (temperature, rate of flow, chemical composition) of a spring.—*R. E. Thompson.*

Innovations in the Field of Rust Prevention. A. V. BLOM. Chem.-Ztg., 50: 885–6, 1926. From Chem. Abst., 21: 371, February 10, 1927.—*R. E. Thompson.*

Corrosion Damage to Steam Turbines. ERICH BUCHHOLTZ. Korrosion, 1: 29–30, 1926. From Chem. Abst., 21: 371, February 10, 1927. This is largely due to water droplets in steam.—*R. E. Thompson.*

Corrosion of Cast Iron. E. C. DICKINSON. Bull. Brit. Cast Iron Research Assoc., 1926, No. 14, 14–6. From Chem. Abst., 21: 371, February 10, 1927. Review of experimental research on corrosion of cast iron. Points discussed are: theory of corrosion, comparison of corrosion of cast iron and of steel, and conditions influencing rate of corrosion.—*R. E. Thompson.*

Determination of Free Alkali in Dakin's Solution. VIRGILIO LUCAS. Rev. chim. pharm. militar 1: 17–9, 1925. From Chem. Abst., 21: 431, February 10, 1927. Of all methods recommended for reduction of sodium hypochlorite prior to addition of phenolphthalein, sodium thiosulfate alone gave good results.—*R. E. Thompson.*

Long-Time Tests of Concrete Using Various Coarse Aggregates. P. J. FREEMAN. Eng. News-Rec., 99: 879–80, 1927. Long-time (10-year) tests were carried out on concrete made with furnace slag, limestone, granite, trap rock, and gravel as coarse aggregate. Regardless of the coarse aggregate employed, concrete increased in strength when stored in dry air up to the age of 1 year, and after that time decreased in strength so long as such storage was continued. Strength was regained after storage in the weather, and at the end of 10 years it had exceeded its 1-year strength. Use of slag of varying composition and weight did not vary the strength of the concrete

in proportion either to the weight or to the content of any constituent.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

New Feature of Lewis Traveling Girder Speeds Tunnel Driving. Eng. News-Rec., **99**: 933, December 8, 1927. Illustrated description of recent material improvement in design of Lewis girder used in driving Moffat tunnel by heading and bench method in soft ground.—*R. E. Thompson.*

Toe Erosion Below Overfall Dams. SHERMAN M. WOODWARD. Eng. News-Rec., **99**: 974, December 15, 1927. Brief discussion of use of hydraulic jump for dissipating kinetic energy below dams, of conditions necessary for successful application of method, and of reasons for failures.—*R. E. Thompson.*

Tunneling at Musconetcong Now and Fifty Years Ago. Eng. News-Rec., **99**: 988–92, December 22, 1927. 1036–40, December 29, 1927. Comparison is made of methods employed in construction of the two railway tunnels through Musconetcong Mountain, built in 1872–5 and 1926–8 respectively. Former is 4829 feet long with rock section 21 feet high and 26 feet wide; latter, 4840 feet long, 30 x 25 feet in section, parallel to and 130 feet south of old tunnel.—*R. E. Thompson.*

Gen. Jadwin Reports on Flood Protection System from Mississippi River. Eng. News-Rec., **99**: 961–6, December 15, 1927. Essential recommendations contained in report of Major-Gen. EDGAR JADWIN, Chief of Engineers, United States Army, just transmitted to Congress by the President with his endorsement. Policy of depending on levees only is for first time abandoned, this system being declared incapable of providing for maximum predicted flood. Estimated cost of protection works is $296,400,000.—*R. E. Thompson.*

Commission Finds Mississippi Flood Control to Cost $684,000,000. Eng. News-Rec., **99**: 1006–8, December 22, 1927. Complete control of Mississippi River floods is estimated by Mississippi River Commission to cost $684,000,000 without land cost or damages, or more than twice amount stated by Major-Gen. EDGAR JADWIN. The two projects, with some exceptions, are similar.—*R. E. Thompson.*

Two Venturi Meters in Series with Range of 1:100. Eng. News-Rec., **99**: 966, December 15, 1927. Brief illustrated description of arrangement of 2 venturi meters with range of 1:100 designed by Chief Engineer HENLE of Munich, Bavaria, and built for spring water supply of Thalheim-Muehlthal. —*R. E. Thompson.*

Composite Gravity and Hollow Type Dam of Pit River. Eng. News-Rec., **99**: 994–5, December 22, 1927. Brief illustrated description of Pit 4 dam completed by Pacific Gas and Electric Company on Pit River in July, 1927. There is solid rock foundation on one side of stream and comparatively soft underlying strata on opposite bank. Combination gravity and hollow type concrete dam selected kept cost within reasonable limits and fully satisfied foundation requirements.—*R. E. Thompson.*

The Sliding-Gage Colorimeter and the Determination of Minute Quantities of Ammonia, Nitrite, Lead, and Iron. A. L. BERNOUILLI. Helv. Chim. Acta, **9**: 827–40, 1926. From Chem. Abst., **21**: 30, January 10, 1927. The very precise colorimeter described was developed by Fuess of Berlin-Steglitz and is undoubtedly the most accurate colorimeter yet devised. Utilizing the dark color that ferric ions give with pyrocatechol, 0.002 mg. of iron in 0.1 cc. can be determined with accuracy of 0.4–1.0 per cent. Instrument is particularly suitable for determination of ammonia, nitrite, lead, and iron in water.—*R. E. Thompson.*

A Modification of the Gillespie Method of Determining Hydrogen-Ion Concentration. J. MCCRAE. Analyst, **51**: 287–90, 1926. From Chem. Abst., **21**: 30, January 10, 1927. Description of apparatus for colorimetric determination of H-ion concentration designed to avoid inconvenience of having to make a large number of volumetric and drop measurements.—*R. E. Thompson.*

The Disinfecting Power of Chloramine (Von Heyden). ADOLPH KOSER. Centr. Bakt. Parasitenk. I. Abt., **99**: 164–71, 1926. From Chem. Abst., **21**: 113, January 10, 1927. Chloramine (Von Heyden) has 25 per cent available chlorine. It will remain unaltered for 15 days in dark glass. Concentration of 1:500 in culture media will inhibit B. coli. A 0.5 per cent solution will kill B. coli in 10 minutes.—*R. E. Thompson.*

Water Softener. H. A. KERN. U. S. 1,604,124, October, 1926. From Chem. Abst., **21**: 147, January 10, 1927. Substantially permanently liquid composition for softening water comprises sodium aluminate, sodium hydroxide and water. U. S. 1,604,125 specifies clarifying water by adding reaction products formed from hydrated lime and solution of sodium aluminate and sodium hydroxide. U. S. 1,604,126 specifies forming water-softening composition by adding sodium carbonate to sodium aluminate solution in sufficient quantity to take up solvent as water of crystallization and form solid product.—*R. E. Thompson.*

Wells and Springs of Dorset. W. WHITAKER and WILFRID EDWARDS. Mem. Geol. Survey England, 1926, 114 pp. From Chem. Abst., **21**: 145, January 10, 1927. Geological structure discussed in relation to water supply. Local supplies described and analyses given.—*R. E. Thompson.*

Method for the Combined Determination of Oxygen Absorbed and Albuminoid Ammonia in Sewages and Effluents. J. W. HAIGH JOHNSON. Analyst, **51**: 345, 1926. From Chem. Abst., **21**: 145, January 10, 1927. After distilling off free ammonia in usual way, leaving volume of approximately 250 cc., add 25 cc. of 20 per cent sodium hydroxide and 20 cc. of 0.125 normal potassium permanganate. Heat with reflux condensation for 30 minutes, cool and make up to 500 cc. Remove 2 separate portions of 50 cc. each, acidify, add potassium iodide and titrate with sodium thiosulfate. Each result gives the oxygen absorbed by 0.1 original volume and is 4 times result for 4 hours

at 80°F. Return remaining 400 cc. to flask and distil off ammonia and nesslerize. This gives albuminoid ammonia for 0.8 original volume and is slightly higher than ordinary Wanklyn value.—*R. E. Thompson.*

Modification of the Kjeldahl Method for Determining Organic Nitrogen in Sewage Effluents. J. W. Haigh Johnson. Analyst, **51**: 405, 1926. From Chem. Abst., **21**: 146, January 10, 1927. Kjeldahl process gives unsatisfactory results in presence of nitrates and nitrites. Suggested that large amounts of free and saline ammonia be first removed by usual distillation, and then nitrites by distillation after acidifying with 2 cc. 7 normal sulfuric acid. When nitrites cease to appear in distillate, reduction of nitrates may be effected by adding 0.5 gram zinc dust with 10 cc. 7 normal sulfuric acid. Solution should be boiled in reflux condenser for 15 minutes. Kjeldahlization can then be carried out in usual manner.—*R. E. Thompson.*

Water Supplies on Canadian Great Lakes Vessels. G. H. Ferguson. Public Health Reports, **42**: 16, 1097–1101, April 22, 1927. To apply regulations for the standard quality of water for drinking and culinary purposes, physical examinations of water supply systems installed on Great Lake vessels were made in 1923 and 1924. 908 routine visits to Great Lake vessels were made in 1925. Contact with health and navigation officials by correspondence and interviews was necessary. Considerable coöperative work with the U. S. Public Health Service was carried on. The supervision of vessel water supplies is a considerable problem owing to the large number of vessels and extent of traffic. A continual check on these supplies is necessary to keep to a minimum typhoid, dysentery, and diarrhea outbreaks from such sources. —*R. E. Noble.*

Report of a Typhoid Epidemic in Grafton, W. Va., During the Winter of 1926–27. E. S. Tisdale. Public Health Reports, **42**: 18, May 6, 1927. During December, 1926, and January, 1927, 150 cases of typhoid occurred with 25 deaths. The pumping station chlorinator was found to be partially crippled and tests for residual chlorine were negative. The chlorinator had been shut down for repairs sometime during the preceding month. Stools from typhoid patients at Arden, 20 miles upstream from Grafton, had been thrown on the banks of a small stream leading to the river. The full-time city and county health officer, during his term of office had carefully watched the water supply. As an economy measure the full-time health work was discontinued by the county court some months previous to the epidemic with consequent neglected supervision of this supply. Preventive measures were taken and conditions corrected.—*R. E. Noble.*

Responsibility of Interstate Common Carriers in Supplying Safe Drinking Water to Passengers and Crew. Isadore W. Mendelsohn. Public Health Reports, **42**: 13, 868–871, April 1, 1927. The legal responsibility of companies transporting passengers in interstate traffic for the safety and welfare of the passengers and crew is pointed out. The interstate quarantine regulations of the United States are referred to. Cases and court decision concerning

an outbreak of water borne disease due to polluted drinking water on two lake vessels are cited.—*R. E. Noble.*

Court Decisions Relating to Public Health. Public Health Reports, **42:** 14, 925–927, April 8, 1927. **Compensation Granted under Workmen's Compensation Act for Death from Typhoid Fever.** Illinois Supreme Court; John Rissman and Son *vs.* Industrial Commission et al., 154 N. E. 203; decided Oct. 28, 1926. **Typhoid Fever Held Not Compensable under Workmen's Compensation Act.** Texas Commission of Appeals, Section B. Buchanan et al. *vs.* Maryland Casualty Co., 288 S. W. 116; decided Nov. 24, 1926. **Act Authorizing Construction and Operation of Public Water Supply System and Proceedings Thereunder Upheld.** Virginia Supreme Court of Appeals; Kirkpatrick et al. *vs.* Board of Supervisors of Arlington Co. et al., 136 S. E. 186; decided Nov. 26, 1926.—*R. E. Noble.*

Court Decisions Relating to Public Health. Public Health Reports, **42:** 26, July 1, 1927. **Injunction to Restrain Enforcement of Ordinance for Prevention of Pollution of Source of City's Water Supply, Located in United States Forest Reservation, Denied.** Washington Supreme Court; Brown *vs.* City of Cle Elum, 255 P. 961; decided April 28, 1927.—*R. E. Noble.*

Purification of Swimming Baths Water.—A Leeds Installation. Surveyor, **72:** 1865, 374, October 21, 1927. A brief article covering the purification plant for the two swimming baths at Holbeck. The combined capacity of the baths is 103,000 gallons. The water circulated through the purification plant once each six hours, is taken from the deep end of the bath by an electrically driven pump and discharged to the chemical mixing and storage tanks from which it passes through two 8-foot pressure filters. The water is heated and aerated before returning to the pool, aeration being supplied by compressor. —*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

The Water Purification Equipment of the Public Baths of St. Gallen. W. Grimm. Chemical Abstracts, **21:** 15, 2519, August 10, 1927. "The pool has a surface of 200 sq. m., a water vol. of 300 cu. m. and accommodates about 61,000 people a year. 50,000 cu. m. a year of the standard drinking water supply is required. It is kept at a temperature of 23.5°. The water is withdrawn from the deep end, passed through a rapid sand filter, chlorinated and returned to the shallow end."—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

State Regulation of Bathing Places. Arthur M. Crane. Jour. American Association for Promotion of Hygiene & Public Baths, **9:** 30, 1927. Writer notes in discussion of the American Public Health Association Report of the Joint Committee on Bathing Places that it is quite within the province of duly constituted health authorities to specify a certain degree of purity of pool water and this to be enforced by the police power of the state.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Layout of Accessory Equipment in a Modern Swimming Pool. J. FREDERICK JACKSON. Eng. News-Rec., **98:** 6, 232, February 10, 1927. Description of a new pool located at the St. Francis Orphan Asylum, New Havem, Conn. One important point in the design is that the water supply line, drains for outlets and scum gutters and pipe for vacuum cleaner are all placed in a passage in the basement where they are accessible.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

New Water Softening Plant for Beverly Hills, California. R. L. DARBY. Western Construction News, **2:** 20, 31, October 25, 1927. Beverly Hills derives its water supply from various wells averaging 15 or 16 grains per gallon hardness and 8 or 10 p.p.m. hydrogen sulphide. After experimental work on a 70,000 g.p.d. plant a 5 m.g.d. plant was designed to include: aeration; coagulation with lime and alum; sedimentation; secondary alum coagulation; secondary sedimentation; filtration. Chlorination is provided to be added at any point after aeration. It will probably be used after secondary sedimentation. Aeration will remove 40 to 60 per cent of the hydrogen sulphide. The aeration house is covered and closed on the east and north, the south and west being open to take advantage of trade winds. In the northeast corner is a ventilating tower 118 feet high with a 6 foot stack provided with an oil burner at the base. Primary coagulation tanks with motor-driven mixing paddles are followed by a Dorr Clarifier with sixty minute retention period. The water then flows through secondary coagulation tanks similar to primary tanks and then to 2 sedimentation basins with five hours' retention period. Split alum dosage and long retention has been found economical and permits the greatest reduction of hydrogen sulphide. Five filter units of 1 m.g.d. each are provided, and the design allows for five additional units on the opposite side of the pipe gallery. Clear water reservoir has a capacity of 5 million gallons.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

The Upper San Leandro Filtration Plant of the East Bay Water Company, Oakland, California. WILFRED F. LANGELIER. Western Construction News, **2:** 19, 77, October 10, 1927. The upper San Leandro Filtration Plant is a thoroughly modern plant of 12 m.g.d. capacity, designed to handle the supply from Upper San Leandro Reservoir. In addition to high turbidity and color at certain seasons, traces of manganese were expected in the raw water, as has been found at the neighboring San Pablo plant where it badly coated the sand grains and impaired the efficiency of filter units. The plant consists of nozzle aerators; 4 coagulation units, each 20 feet in diameter by 20 feet deep, with motor operated stirring mechanisms; sedimentation basins of 2,000,000 gallons capacity arranged in duplicate for series or parallel flow and for double coagulation; four 3 m.g.d. filter units, bifurcated so that half units may be washed; chlorinators for treating raw and filtered waters; a 3,000,000-gallon filtered water storage reservoir and provision for recovery of wash water.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Residual Germicidal Action of Water Treated with Ultra Violet Rays. C. E. BERNDT. Jour. American Association for Promoting Hygiene and Public

Baths, 9: 36, 1927. The proper exposure of water to ultra violet rays destroys bacterial life without adding odor, taste or irritating qualities to the water. When used in connection with swimming pools with re-circulating systems the results obtained are far better than the law of purification by consecutive dilution would indicate. According to this law, two turnovers of a pool water per twenty-four hours would indicate a removal of 63 per cent of the impurities. Tests made using ultra violet ray sterilization show much better results.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Swimming Pool Sanitation a Public Health Problem. H. P. Croft. Jour. American Association for Promoting Hygiene and Public Baths, 9: 34, 1927. That the control of indoor and outdoor swimming pools by health authorities is desirable for the promotion of public health is evidenced by two states having statutory regulations; seven state health departments adopting rules and regulations; eight state health departments acting in an advisory capacity; and eight others preparing or considering the preparation of rules and regulations.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

California State Board of Health—Rules Governing Sanitation, Safety and Cleanliness of Swimming Pools. Jour. American Association for Promoting Hygiene and Public Baths, 9: 65, 1927. The new rules were adopted in 1926 and cover the bacteriological quality of the pool water, cleanliness of pool water, sanitation of premises, sputum contamination (by requiring a scum gutter), diseased persons, dressing room and sanitary conveniences, safety of bathers, laundry, operating records and report, with application for permit. Notes accompanying the rules cover the question of construction, water supply and water treatment, including disinfection and copper sulphate treatment. Applications must be made and permits granted by the Bureau of Sanitary Engineering of the State Board of Health. Where construction is contemplated a report including detailed plans must be submitted.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Specifications and Analyses of Gravel and Filter Sand—Where Sand may be Obtained. Lewis O. Bernhagen. Proc. Ninth Texas Water Works Short School, 169, January, 1927. Modern filter plant operators must produce good water at low cost. The perforated underdrain system has resulted in economy in construction and operation but demands extreme care in selecting and grading the gravel bed. Complete specifications for gravel are included. "Gravel should not have flat surfaces." Gravel should be uniformly graded, washed and placed carefully in five layers. Filter sand should be round rather than sharp. Other specifications for sand depend upon the water to be handled. Complete specifications for sand for filtering an average water are given. Suitable gravel may be found in Texas. "An almost ideal filter sand may be obtained at Red Wing, Minn."—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Determining Coagulant Dosage by Bottle Tests. Lewis I. Birdsall. Proc. Ninth Texas Water Works Short School, 264, January, 1927. River waters

change rapidly in quality. These changes require corresponding changes in the amount of coagulent to be used in a water purification plant. Procedure is outlined for bottle tests to appraise the amount of coagulant required.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Iowa's Water Supply Problem in Its Relation to Sewage Disposal. Hans V. Pederson. Bulletin 88, Engineering Extension Dept., Iowa State College, 18, March 5, 1927. After pointing out stream pollution conditions in Iowa and the sources of sewage and industrial wastes, the writer states that the number of public surface water supplies in Iowa will increase and recommends early and proper treatment of the wastes to prevent pollution of the streams. —*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Developing and Protecting Underground Water Supplies. J. G. Montgomery. Proc. Ninth Texas Water Works Short School, 125, January, 1927. Discusses protection of underground water supplies with particular reference to Texas conditions. Includes instructions developed by Layne-Texas Company to prevent pollution of new wells during construction and to provide initial disinfection upon completion. "After well has been completed and developed six 2-ounce capsules of chloride of lime for each 100 gallons of water within the pipe should be sent to the bottom of the well. Should not be pumped again for forty-eight hours." *A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

The Determination of Available Chlorine in Water-Sterilizing Powder (Chlorine) by Means of the Horrocks Box and Hypo Tablets. S. Elliott. Jour. Royal Army Medical Corps, **49**: 2, 116, August, 1927. A method, not as accurate as those of the laboratory but sufficiently so for rough work in the field, for determining the amount of available chlorine in water-sterilizing powders, is described. The method contemplates the use of the Horrocks Box, but gives capacities of cups and scoops included in such box, and gives the strength of the few solutions used. The method is simple, and it should take only a few minutes to make such a test.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

The Value of Methods for the Differentiation of Bacilli of the Coli-Aerogens Group, When Applied in Shanghai. E. P. Hicks. Jour. of Hygiene, **26**: 3, 357, August, 1927. The collection made of the coli-aerogenes group included the following strains: 100 from human, 50 from animals, and 50 from soil. The tests applied were: Methyl red, Voges-Proskauer, Koser's Citrate, and indol production. Before each test the respective media were incubated for five days at 37°C. Very little difference was noted between the fecal strains from human and animal sources. Author concludes in part that the citrate and indol tests are of value, the citrate being the better of the two, and that the methyl red and Voges-Proskauer tests are of no value.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Note on the Aeration of Water. Gilbert J. Fowler and S. N. Chatterjee. Surveyor, **72**: 1855, 139, August 12, 1927. An apparatus, consisting princi-

pally of 3 aspirator bottles and an aeration chamber made of the outer jacket of a Liebig Condenser, arranged to determine the amount of oxygen that is dissolved from surface streaming and from air bubbles passing through the liquid in the condenser is described. When water containing about 1.0 p.p.m. of dissolved oxygen was allowed to stand in the condenser with only a small tube open to the air the oxygen content was increased to 1.2 p.p.m. in twenty-four hours. When the condenser was not quite full, leaving an area of water equal to the cross section of the condenser exposed, the solution of oxygen from the streaming effect was increased to 5.0 p.p.m. after standing an additional twenty-four hours. However if air was slowly bubbled through the water in the condenser for only ten minutes the oxygen contents was increased 1.0 to 5.0 p.p.m. The authors present this experiment to controvert the opinion that probably only a very minute quantity of oxygen is absorbed by sewage as air passes through it and that most of the aeration takes place at the surface.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Interstate Control of Stream Pollution. JOHN E. MONGER. Nation's Health, 9: 8, 16–18 and 68, August 15, 1927. Writer believes that the State Health Department is the logical organization to exercise control of stream pollution. Citation is made of the coöperation of nine state health departments which are interested in the control of the Ohio River system. "The possibilities of coöperative action among the states, and particularly the health departments of the states, are apparently unlimited and with the development of a conscience by the states, the stream pollution problems as affecting one another may be solved without the intervention of federal agencies.—*A. W. Blohm* (*Courtesy U. S. P. H. Eng. Abst.*).

Elimination of Errors in the Ortho-Tolidin Method. F. R. MCCRUMB. Journal N. E. Water Works Association, 41: 4, 386, December, 1927. Factors to be considered are; turbidity; alkalinity of material; presence of interfering substances as manganese, iron, nitrites; time of development and duration of *ortho*-tolidin color; effects of temperature and light. Experiments were performed at laboratories of LaMotte Chemical Products Company, Baltimore, Maryland. Comparator method adopted, and new standards had to be established. This was done by using solutions of potassium dichromate and copper sulfate checked by sodium thiosulphate titration, and *ortho*-tolidin Nessler tube method. Satisfactory results secured on turbid and colored solutions by comparator method over range 0.1 to 10 p.p.m. of chlorine in presence of turbidity, color, and interfering substances as manganese, iron, and nitrites. The pH at time of color formation, to give a satisfactory color on *ortho*-tolidin test, found to be not over 2.0. Hydrochloric acid can be put in the *ortho*-tolidin reagent with one gram of *ortho*-tolidin, to the amount not over 98 g.p.l. at 25 ± 1°C. The *ortho*-tolidin color reached its maximum in from one to three minutes and lasted 20–30 minutes, when used in water. In case of sewage and trade wastes it developed in from one to fifteen minutes (usually in less than 5 minutes) after which fading of color set in. It is advisable to take the reading at the time the maximum color is developed.—*Carl Speer, Jr.*

Cross-Connections in Connecticut. Warren J. Scott. Journal N. E. Water Works Association, **41**: 4, 365, December, 1927. Cross-connections between potable water supplies and impure supplies constitute important problem to health and water works authorities. Courts recently show tendency to hold water works owners responsible for elimination of dangerous cross-connections. In Connecticut in May, 1926 public hearings at State Capitol were held to discuss proposed sanitary-code regulations which, after a second hearing, were adopted. Immediately work was begun to eliminate cross-connections, or to protect them by double check-valves under permit. Double check-valves were permitted only on the understanding that arrangement was temporary and after each one had been tested by officer of Health Department. Method of testing valves explained with diagram and written material. Results to date show new types of valves to be giving good results provided they are properly maintained. Types of cross-connections found are: (1) fire service, (2) industrial use, (3) boiler feed, (4) pump priming, (5) auxiliary drinking water. Complete separation is the only really satisfactory procedure.—*Carl Speer, Jr.*

Public Works and State Boundaries. Clemens Herschel. Journal N. E. Water Works Association, **41**: 4, 331, December, 1927. Article brings out need of reciprocity between states in matters of public works construction, same as in trade and travel, if we are not to waste millions of dollars in expensive construction work in order to avoid crossing state borders. Methods suggested are: (1) Compact between states concerned. (a) Requires consent of Congress to become effective. (2) Equitable relief through action of Federal Courts. (a) Likely to consume years of time and then have no satisfactory ending. (3) Concurrent legislation by adjoining states. (a) Not obligated to seek approval of Congress. (4) Multiple state charters. (a) Procure legislation in any one state on a matter of no direct importance to it by throwing open subscription to stock of water company to everybody, up to the limit of one less than half the number of shares issued, with the interested municipality in reserve to take up all remaining unsubscribed stock. (b) Ruling considerations for planning and construction then will be natural resources as found.—*Carl Speer, Jr.*

Interstate Water Rights. Caleb M. Saville, Journal N. E. Water Works Association, **41**: 4, 340, December, 1927. The Federal Government regulates interstate streams only for navigation purposes. All other interest and authority rest with states or individuals and are limited to the holding in trust of common property for benefit of citizens. No state has a right to pollute the water so as to make it unfit for use in another state. A distinction is made between surface water and underground water. Surface water usefulness is considered under three heads: (1) riparian rights; (2) prior appropriation; (3) reasonable use. It is customary for states to settle disputes of distribution of water in interstate streams by compact or concurrent State Legislation. Numerous examples of claims and disputes with decisions and agreements are cited.—*Carl Speer, Jr.*

Making Money out of Filter Sludge. A. W. BULL. Water Works Engineering, **80**: 25, 1687, November 23, 1927. Chemical reactions involved in water softening proceed slowly at low temperatures. Even after 15–20 hours the water will be found to contain greater quantities of calcium and magnesium ions than should be present in saturated solutions of the precipitated compounds. One method of reducing this super-saturation, or lack of reaction, is by introducing to the water sludge from the coägulation basins. From experiments conducted at Columbus, Ohio, and Pittsburgh, Pa., the following conclusions were drawn: "(1) the return of sludge is of distinct benefit in water softening practice; (2) the beneficial results are due either to a catalytic speeding up of the reaction or, more probably, to a reduction in supersaturation." By increasing the concentration of solids in water prior to sedimentation, clearer effluent can often be obtained than by plain sedimentation without the addition of excess solids. Sludge which is returned in water softening is a chemical precipitate without any further capacity for absorbing lime, whereas the river mud removed by presedimentation has shown a marked tendency to remove lime from solution and to increase the quantity of chemicals needed for softening.—*Carl Speer, Jr.*

Methods Used in Denver to Clear Clogged Service Pipes. H. D. GROSS. Water Works Engineering, **80**: 25, 1759, December 7, 1927. Service pipes in Denver are made of lead "XX" strong. They are cleaned by opening faucet in rear of building and then opening and closing the curb cock, working rapidly. If this does not clean pipe, service in the basement of building is disconnected, several handfuls of rock salt put in end of pipe leading to main, wad of tissue paper placed on top of rock salt, and force pump connected. Service pipes are also cleaned with acid. This process is very effective.—*Carl Speer, Jr.*

NEW BOOKS

Municipal and Rural Sanitation. VICTOR M. EHLERS and ERNEST W. STEEL. First edition, 448 pages, 119 cuts, 1927. Published by McGraw-Hill Book Company, Inc. This book covers in a general way, the entire subject of sanitation, devoting a chapter to each of the following: Communicable Diseases; Principles of Excreta Disposal; Excreta Disposal without Water Carriage; Excreta Disposal with Water Carriage; General Characteristics of Water; Treatment of Water; Protection of Water Supplies; Refuse Collection; Refuse Disposal; Mosquito Characteristics; Mosquito Control Methods; Organization of Anti-Mosquito Campaigns; Fly Control; Rodent Control; Milk Sanitation; Food Sanitation; Plumbing; Ventilation; Light; Housing; School Sanitation; Industrial Hygiene; Tourists Camps; Swimming Pool Sanitation; Miscellaneous; Disinfection; Vital Statistics and Public Health Organizations. It has been the aim of the authors to place in convenient form the knowledge which the sanitarian requires. They have produced a volume which should be of valuable assistance to both the layman and the sanitarian.—*A. W. Blohm.*

The Water Resources of Rhode Island. Report of the Commission appointed to investigate the sources of water supply for cities and towns, to the General Assembly at the January Session, 1928. Pamphlet, 126 pages, (1928).

The report discusses the water resources of the State from the standpoint of the geologist, the chemist and the engineer. The section on "Geology, Climate and Run-off," by Charles Wilson Brown, reviews the geological formations, the climatic factors including temperature, precipitation and evaporation and the run-off which averages from 50 to 60 per cent of the rainfall.

The quality of the water supplies is ably discussed by Stephen DeM. Gage, under three general classes, namely: surface supplies without purification, used by 33.9 per cent of the entire state population, filtered surface supplies used by 62.3 per cent, and ground water supplies, used by 3.8 per cent of the total population. The physical and chemical characteristics and bacterial content of the individual public supplies are given in tabular form. Data concerning disinfection of certain of the public supplies are presented. The sanitary quality of 1.797 rural wells, as disclosed by examination, showed that 52 per cent were safe for domestic use, 23 per cent were doubtful and 25 per cent were unsafe.

The engineering features such as populations supplied, drainage areas, rivers and streams, water supply developments, etc., are summarized by George H. Leland. Many detailed statistics are presented in the form of tables, including the physical characteristics of each of the public water supplies of the State.—*J. K. Hoskins* (*Courtesy Public Health Engineering Abst.*).

Report on Cast Iron Pipe. Seventy-Fifth Annual Report, Board of Water Commissioners, Detroit, Michigan, for the Year Ending June 30, 1927. Page 21. At the request of this Board, a report was prepared under date of July, 1926, entitled, "A Study of Centrifugally Cast Pipe vs. Sand Cast Pipe for the Water Board of the City of Detroit," by Professors F. N. Menefee and A. E. White, Department of Engineering Research, University of Michigan. The following is taken from that report:

"Foreword. This report has been jointly prepared by Professors F. N. Menefee and A. E. White. The thickness measurements, the radial compression, tensile, transverse and impact tests, with computations thereon, were made under the direct supervision of Professor Menefee.

"While this report was in preparation, a paper dealing with practically the same subject, 'A Study of the Relation Between Properties of Cast-Iron Pipe Tested Under Impact, Internal Pressure, and Flexure, and the Corresponding Properties Found in Several Kinds of Test Specimens Taken Therefrom,' by Arthur N. Talbot and Frank E. Richart, was read before the American Society of Testing Materials at their annual meeting, June 21st to 26th, 1926.

"The object of this investigation has been to determine the relative merits of Centrifugal Cast Iron Pipe and Sand Cast Pipe as requested in order No. 4112 by the Water Board of the City of Detroit, Dated November 16th, 1925.

"The work performed required physical, chemical, and metallographic tests on forty-eight (48) pieces of pipe. Four (4) of the pipes tested were shipped to the University of Michigan in November, 1925, and forty-four (44) were picked out by Professors Menefee and White at one of the Detroit yards of the Water

Board in December, 1925. They were received at the University in January, 1926. The report is likewise based on data and information secured when Professor White visited the Alabama plant of the United States Cast Iron Pipe and Foundry Company in February, 1926.

"No attempt has been made in this report to cover such phases as installation, maintenance, tests of joints, and other matters of a similar character.

"Summary. Our findings with regard to the respective merits of centrifugally and sand cast pipe follow:

IMPORTANCE OF TESTS	TESTS	FAVOR
Primary	(2) Variation in thickness	Centrifugal
Primary	(1) Tensile	Centrifugal
Primary	(4) Impact	Sand cast
Primary	(5) Radial compression	Sand cast
Primary	(3) Removal of strains	No decision
Secondary	(1) Radial deflection	Centrifugal
Secondary	(3) Inside smoothness	Centrifugal
Secondary	(5) Cutting	Centrifugal
Secondary	(6) Metallographic	Centrifugal
Secondary	(2) Transverse	Centrifugal
Secondary	(7) Hardness	Centrifugal
Secondary	(4) Resistance to corrosion	No decision
Secondary	(8) Chemical	No decision

"The thirteen headings shown above represent the main subdivisions of the investigation. The first five are the ones of outstanding importance. Opinion might differ on the division, but in the main it is believed that we are correct in thus weighing the different tests into ones of primary and ones of secondary importance.

"We find considerable hinges around the character of the annealing operation which forms a part of the centrifugal pipe manufacturing practice. Though as at present performed it is, in most cases, adequate for the removal of strain, yet if opportunity were provided for the pipes to cool more slowly through the critical range they would possess a much higher resistance to shock from impact, there could be no question about the complete removal of strains and the hardness conditions would be improved, or at least not adversely affected. What change, if any, on the radial compression and transverse properties would result from a lengthening of the anneal, is problematical. We feel a longer anneal would not adversely affect these properties. The chances are it would improve them.

"Our final recommendations, therefore, follow:

"1. With present practice and on basis of similar costs, we can find no outstanding advantage to either the centrifugally cast or the sand cast pipe.

"2. With present practice and on the basis of lower costs for the centrifugally cast pipe, we favor the purchase of centrifugally cast pipe.

"3. If the annealing practice were modified as suggested above, we would, on the basis of similar costs, recommend the purchase of centrifugally cast pipe."—*Abel Wolman.*

SUBJECT INDEX

AUTHOR INDEX

INDEX TO ABSTRACTS

I. Authors

INDEX TO ABSTRACTS

II. Subjects

APPLICATION FOR MEMBERSHIP

IN THE

AMERICAN WATER WORKS ASSOCIATION

Date:..

...............................**hereby make application for**..

Membership in the American Water Works Association, and enclose herewith the

sum of..**Dollars, the required initiation fee**

and one year's dues in advance.

Name..

Title or Business..

Address..

....

....

Business or Professional Experience..

....

....

....

Recommended by..

Recommended by..

29 West 39th Street

Send application to American Water Works Assn., [redacted] New York, N. Y.

(To fill in blank see extracts from the Constitution on other side)

REPORT OF MEMBERSHIP COMMITTEE

We have investigated the qualifications of the applicant, and approve his

admission to..**membership.**

Date:.. ....**Chairman.**

Date:.. ....

Date:.. ....

ARTICLE III. OF CONSTITUTION

Section 3. An Active Member shall be either a superintendent, manager or other officer of a municipal or private water works; a civil, mechanical, hydraulic or sanitary engineer, chemist or bacteriologist, including those acting technically as such for, and employed by, Associate Members of the Association; or any qualified person engaged in the advancement of knowledge relating to water supply in general. (Initiation Fee, $5.00; Annual Dues, $10.00.)

Section 4. A Corporate Member shall be a water board, water commission, water department, water company or corporation; national state or district board of health or other body, corporation or organization interested or engaged in public water supply work, and shall be entitled to one representative whose name shall appear on the roll of members and may be changed at the convenience or pleasure of the represented Corporate Member upon written request to the Secretary, and who shall have all of the rights and privileges of an Active Member. (Initiation Fee, $10.00; Annual Dues, $15.00.)

Section 5. An Associate Member shall be either a person, firm or corporation, engaged in manufacturing or furnishing materials or supplies for the construction or maintenance of water works. An Associate Membership shall entitle the holder to be represented by one person on the floor at each meeting but such representative shall not be entitled to vote nor take part in any discussion unless permission is given by unanimous consent of the members present. (Initiation Fee, $10.00; Annual Dues, $25.00.)

Membership in the Association carries also membership in its Local Sections, and the Journal, a monthly publication devoted to water works interest. The proceedings of the annual conventions and of the meetings of the Local Sections are published in the Journal, which also contains contributed articles on subjects pertaining to public water supplies.

ADVERTISEMENT SECTION

CLASSIFIED INDEX TO ADVERTISEMENTS

ALPHABETICAL LIST OF ADVERTISERS

48TH ANNUAL CONVENTION, SAN FRANCISCO, CALIFORNIA, JUNE 11-16, 1928

VOL. 19, NO. 6 JUNE, 1928

PROCEEDINGS 47TH YEAR

JOURNAL
OF THE
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PUBLISHED MONTHLY

BY THE

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JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

VOL. 19 JUNE, 1928 No. 6

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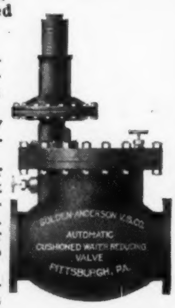

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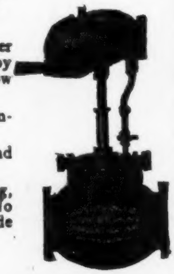

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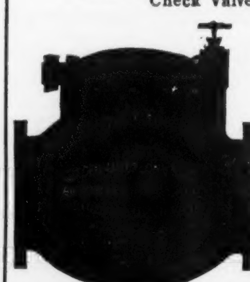

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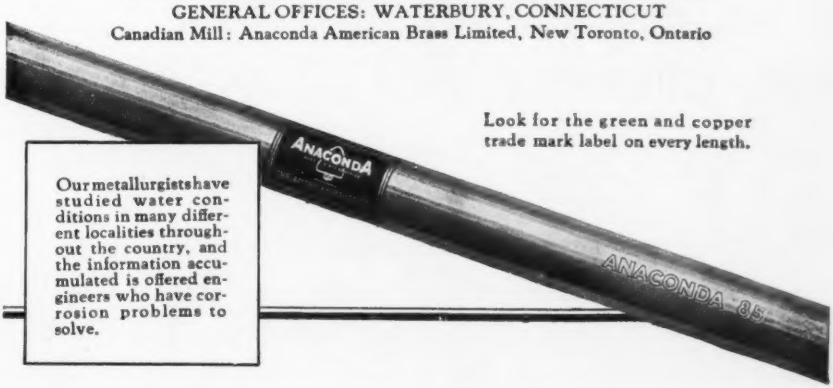

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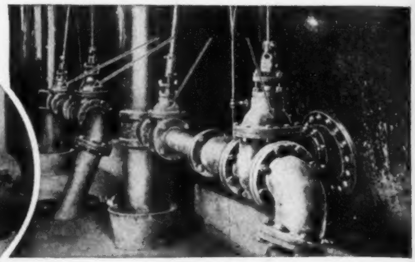

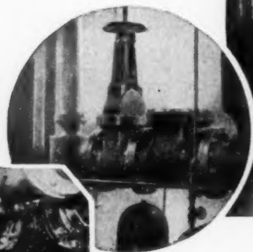

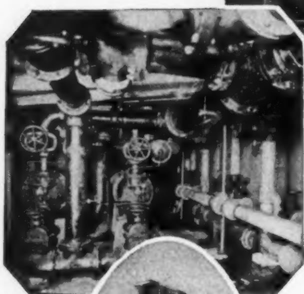

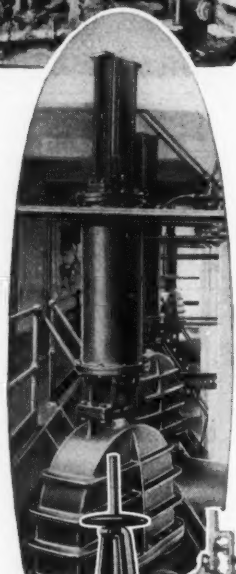

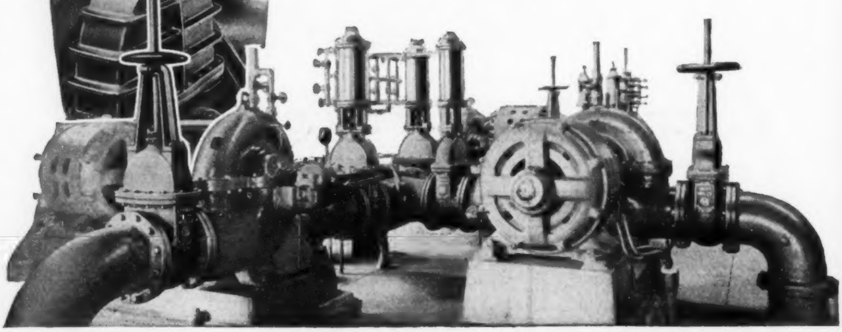

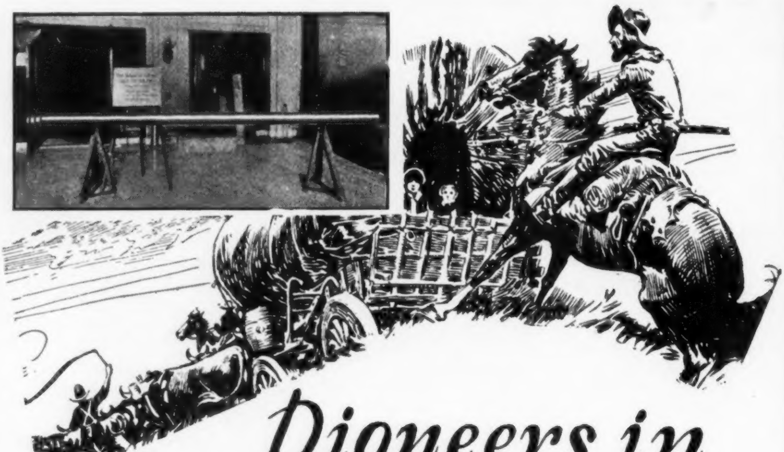

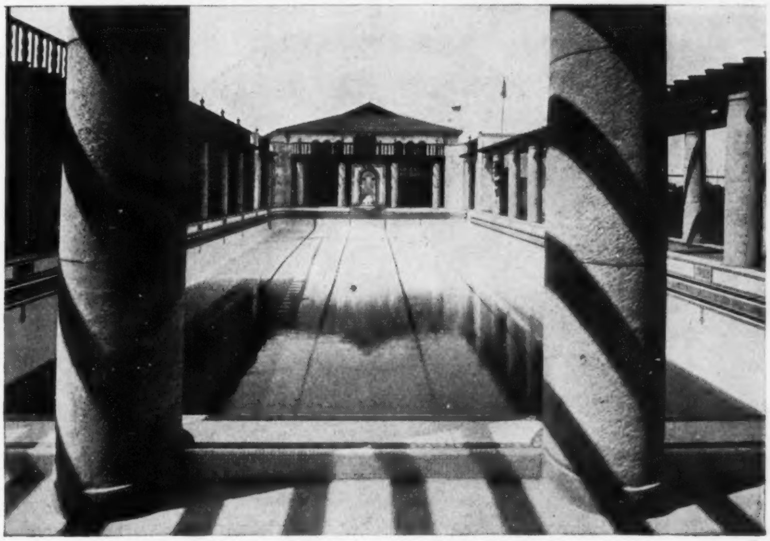

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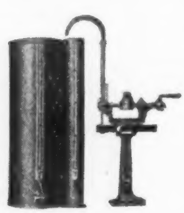

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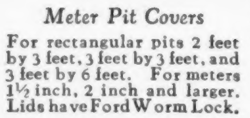

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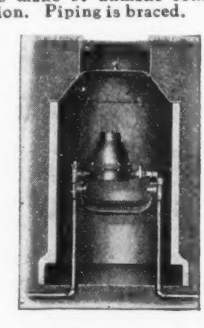

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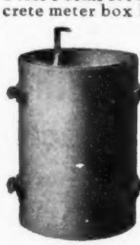

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